

2015

Treatment Efficacy of Manual Therapy on Speech Outcomes in Children with Spastic Cerebral Palsy: A Single-Subject Experimental Design

Chantelle B. Varnado

Louisiana State University and Agricultural and Mechanical College, aballa8@lsu.edu

Follow this and additional works at: https://digitalcommons.lsu.edu/gradschool_dissertations



Part of the [Communication Sciences and Disorders Commons](#)

Recommended Citation

Varnado, Chantelle B., "Treatment Efficacy of Manual Therapy on Speech Outcomes in Children with Spastic Cerebral Palsy: A Single-Subject Experimental Design" (2015). *LSU Doctoral Dissertations*. 3611.
https://digitalcommons.lsu.edu/gradschool_dissertations/3611

This Dissertation is brought to you for free and open access by the Graduate School at LSU Digital Commons. It has been accepted for inclusion in LSU Doctoral Dissertations by an authorized graduate school editor of LSU Digital Commons. For more information, please contact gradetd@lsu.edu.

TREATMENT EFFICACY OF MANUAL THERAPY ON SPEECH OUTCOMES IN
CHILDREN WITH SPASTIC CEREBRAL PALSY: A SINGLE-SUBJECT
EXPERIMENTAL DESIGN

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Communication Sciences and Disorders

by
Chantelle Ballard Varnado
B.A., Southeastern Louisiana University, 1999
M.S., Southeastern Louisiana University, 2001
May 2015

This manuscript is dedicated to my husband and children who have so patiently supported my efforts to extend my education.

ACKNOWLEDGEMENTS

I am profoundly grateful to my mentor Dr. Neila Donovan for her honesty, encouragement, and direction throughout this academic adventure. I am thankful for the model that she has set for me as a scientist, researcher, teacher, and friend.

I extend gratitude to my committee members (Dr. Paul Hoffman, Dr. Arend Van Gemmert, and Dr. Megan Papesh) for their valuable guidance, perspective, and support they provided. They have constantly challenged me and held me to the highest caliber of academic excellence. I also thank Dr. Brittan Barker for her empowering spirit.

To my colleagues past and present that have shaped my practice as a clinician, research agenda, philosophy of teaching, and faith, thank you. My friends at Children's Hospital of Richmond at Virginia Commonwealth University that taught me so much about the value of interdisciplinary treatments and the aspects of other disciplines that can contribute to speech outcomes.

I am indebted to the members of the Communication Outcomes Research Laboratory who assisted in data collection, speech sample transcription, and data input. Also, thank you to Rachel Crowder for assisting with data collection for participants. Thank you to the parents of my participants for trusting me with their most precious children and to the children for being my motivation to continue to pursue my dream of research in this area.

This would not have been possible without the support of my family. In my case, the saying "it takes a village" applies to the completion of this monumental process. Each has assumed roles including homework helper, carpool driver, chef, maid, and the list goes on. Most of all I want to thank God for teaching me patience and to trust in his plan.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS.....	iii
LIST OF TABLES.....	vii
LIST OF FIGURES	viii
LIST OF ABBREVIATIONS.....	ix
ABSTRACT.....	x
CHAPTER 1. INTRODUCTION	1
Establishing EBP	1
Statement of the Problem.....	5
CHAPTER 2. LITERATURE REVIEW	6
Respiratory Treatment Guidelines for SLPs	6
Cerebral Palsy	7
Speech Breathing and CP.....	8
Normal Chest Wall Development.....	9
Atypical Chest Wall Development	13
Treatments.....	17
Research Questions	28
Hypotheses.....	28
CHAPTER 3. METHODS	30
Design	30
Participants.....	30
Treatment Setting.....	31
Investigators	31
Equipment.....	32
Procedures.....	33
Data Collection	36
Data Analysis.....	38
Treatment and Measurement Fidelity	39
CHAPTER 4. RESULTS	41
Sample Demographics	41
Treatment and Measurement Fidelity	54
Reliability Measures	54
Question 1	54
Question 2	55
Question 3	55

CHAPTER 5. DISCUSSION.....	58
Question 1	59
Question 2	60
Question 3	62
Theoretical Implications	63
Research Implications/Future Research.....	64
Clinical Implications.....	68
Limitations	70
CHAPTER 6. CONCLUSION.....	72
REFERENCES	73
APPENDIX	
A. ITEMS IN ROBIN T SCALE.....	80
B. IRB APPROVAL.....	81
C. INFORMED CONSENT	82
D. PHOTO CONSENT FORM	84
E. GROSS MOTOR FUNCTION LEVEL	85
F. COMMUNICATIVE FUNCTION CLASSIFICATION SYSTEM.....	88
G. TREATMENT FIDELITY CHECKLIST	89
H. MEASUREMENT FIDELITY CHECKLIST	90
I. RANDOMIZATION OF TREATMENT TASKS.....	91
J. PARTICIPANT #1 RAW DATA	92
K. PARTICIPANT #2 RAW DATA	93
L. PARTICIPANT #3 RAW DATA	94
M. PARTICIPANT #4 RAW DATA	95
N. PARTICIPANT #5 RAW DATA	96

O. SPRINGER COPYRIGHT PERMISSION	97
P. LITMAN COPYRIGHT PERMISSION	100
VITA	101

LIST OF TABLES

1. Means of Maximum Phonation Time by Age.....	27
2. Design Phases	38
3. Participant Characteristics	41
4. Sound Pressure Level Analysis for Participant 1.....	42
5. Duration Analysis for Participant 1	43
6. Secondary Outcome Measures for Participant 1.....	43
7. Sound Pressure Level Analysis for Participant 2.....	45
8. Duration Analysis for Participant 2	46
9. Secondary Outcome Measures for Participant 2.....	46
10. Sound Pressure Level Analysis for Participant 3.....	47
11. Duration Analysis for Participant 3	48
12. Secondary Outcome Measures for Participant 3.....	48
13. Sound Pressure Level Analysis for Participant 4.....	50
14. Duration Analysis for Participant 4	51
15. Secondary Outcome Measures for Participant 4.....	51
16. Sound Pressure Level Analysis for Participant 5.....	52
17. Duration Analysis for Participant 5	53
18. Secondary Outcome Measures for Participant 5.....	53
19. Intelligibility Across Participants	56
20. SBU Across Participants.....	56
21. Rib Cage ROM Across Participants	57

LIST OF FIGURES

1. Infant and Adult Rib Cage Structure	11
2. Structural Differences	16
3. Sound Pressure Level Data for Participant 1	42
4. Duration Data for Participant 1	43
5. Sound Pressure Level Data for Participant 2	44
6. Duration Data for Participant 2	45
7. Sound Pressure Level Data for Participant 3	47
8. Duration Data for Participant 3	48
9. Sound Pressure Level Data for Participant 4	49
10. Duration Data for Participant 4	50
11. Sound Pressure Level Data for Participant 5	52
12. Duration Data for Participant 5	53

LIST OF ABBREVIATIONS

AAC = Assistive and Alternative Communication

AACPDM = American Academy of Cerebral Palsy and Developmental Medicine

ASHA = American Speech Language and Hearing Association

CP = Cerebral Palsy

EBP = Evidence-Based Practice

fMRI = Functional Magnetic Resonance Imaging

LSVT = Lee Silverman Voice Treatment

MPD = Maximum Phonation Duration

NDT = Neurodevelopmental Treatment

NOD = Non-Overlapping Data

PT = Physical Therapist

ROM = Range of Motion

s = Seconds

SBU = Syllables per Breath Unit

SLP = Speech-Language Pathologist

ABSTRACT

Objective – The present study aimed to determine if a treatment effect is present on speech outcomes in children with spastic cerebral palsy (CP) given 5 sessions of a manual therapy treatment protocol.

Methods – A single-subject experimental design (ABAB) study was devised to establish the treatment efficacy of a manual therapy protocol on speech outcomes in children with spastic CP. The protocol was administered to 5 participants, 4-6 years old. It included five intercostal stretches administered in 15-minute sessions for five sessions. During the withdrawal phase, a sham treatment was administered that included an equal dosage of treatment. Measurements of sound pressure level (SPL) and Maximum Phonation Duration (MPD) of /a/ served as the primary outcomes. Secondary outcome measures included speech intelligibility, syllables per breath unit (SBU), and chest structure measurements.

Results – Trend, level, variability, effect sizes, % of Non-Overlapping Data, and immediacy of effect were combined to support or refute each effect. 15 of 15 demonstrations of effect for SPL, and 9 of 15 demonstrations of effect for MPD were located. This data demonstrate a positive effect on SPL and minimal support for an effect on MPD. Secondary outcome measures of SBU and chest mobility showed a positive treatment effect, while speech intelligibility and abdominal protrusion did not.

Conclusions – This is the first known study to demonstrate a treatment effect in SPL and SBU using a manual therapy protocol, which provide evidence of a likely treatment effect in speech outcomes in children with spastic CP.

CHAPTER 1. INTRODUCTION

The neuromuscular and musculoskeletal systems of children with cerebral palsy (CP) do not develop typically due to restrictions in their movement. Specific to respiration to support speech, the development of the rib cage often occurs without intervention as children's motor skills advance (Parham, 2013) to include oppositional motor movements and crossing midline. Often in children with CP, these changes do not occur without physical and occupational therapy intervention.

In the treatment of respiratory function in children with CP, goals are considered achieved when the patient is able to maintain adequate oxygen levels without the support of a ventilator and/or range of motion (ROM) is adequate to prevent secondary impairments such as contractures (Pin, Dyke, & Chan, 2006; Theis, Korff, Kairon, & Mohagheghi, 2013). The respiratory support required for speech production exceeds that which is needed for life support. Thus, respiratory support treatment may be discontinued well before it is sufficient to support speech. As the physical therapist (PT) continues to address other issues, the speech-language pathologist (SLP) is left with a respiratory system that does not support speech production. This study aims to determine if application of stretch to the chest wall structures will facilitate increased respiration to support speech production.

Establishing EBP

Although treatments in physical, occupational, and speech-language therapy have shown positive clinical change in children diagnosed with CP, many traditional methods are not supported by sufficient evidence to make firm treatment recommendations. Many research efforts offer little direction due to a paucity of consistency and specificity across the treatments studied. The heterogeneity of the studies available regarding speech in patients with spastic CP

makes it difficult to draw definitive conclusions regarding treatment efficacy. The weaknesses described further contribute to the lack of research progress in this population and treatment area. More clearly defined treatment protocols used in both direct and systematic replication could strengthen both the certainty of our knowledge and the generalization of treatments to the entire population of children with spastic dysarthria. Well defined populations, number of participants, standardized treatments, and outcome measures could contribute to the development of treatment plans supported by empirical research (Levy, 2014; Solomon & Charron, 1998). Morgan, Hodge and Pennington (2015) discuss how the deficiency of tools for eliciting connected speech in children with dysarthria limits the measurement of intelligibility and associated measures.

Due to their widely accepted methodology in the establishment of evidence-based practices (EBPs) and contribution in the identification of cause-effect relationships, randomized control trials are highly valued by publishers and researchers (Byiers, Reichle, & Symons, 2012). However, implementing rigorous designs and translating statistical data obtained in these studies to populations of individuals with disabilities have proved difficult and sometimes misleading (Attanasio, 1994; Byiers et al., 2012). Group studies require large, randomly selected, homogeneous, representative groups of participants (Hinkle, Wiersma, & Jurs, 2002). Given the heterogeneous nature of the population of individuals with CP and other severe motor impairments (e.g. variable symptomology, function, and maturation), attaining an appropriately powered homogeneous sample is nearly impossible (Solomon & Charron, 1998).

Another concern caused by the use of group designs is the strict experimental control between participants that may prevent them from receiving optimal treatments (Attanasio, 1994). In neurological rehabilitation, patterns of cognitive, behavioral, and sensorimotor impairments in

patients with the same diagnosis vary, resulting in diverse presentations of function; therefore, treatment should reflect these differences (Perdices & Tate, 2009).

Omitting or failing to adhere to these crucial experimental design components could greatly compromise generalization and internal and external validity (Attanasio, 1994). Furthermore, if rigorous control were achieved, it likely would not reflect the variability present in clinical practice settings. In addition to participant selection and rigid treatment protocols, the feasibility of large-scale studies may be limited due to financial, time, and personnel resources (Kazdin, 2010).

Some have argued the interpretation of the inferential statistics in large group studies has prevented the establishment of a research base applicable to clinical issues (Attanasio, 1994) and masks individual variability (Perdices & Tate, 2009). The statistics obtained in such studies give the probability of obtaining the same results given the same population if the exact study were to be replicated (Attanasio, 1994; Hinkle et al., 2002). The use of manipulated data in measures of central tendency and statistical significance tells little about the effect a treatment has on an individual, thus making direct application to a member of a heterogeneous group with heterogeneous symptoms unclear. The context of the treatment and individual variability is lost as inferential statistics tell only whether a difference in group averages is present (Hinkle et al., 2002).

Because ideal treatment methods are difficult to implement in large-group studies and statistics are challenging to interpret, clinicians have often defaulted to accepted traditional treatments that have little to no research support. In fact, rather than attempting new treatments that have limited research support, SLP's sometimes choose to continue to use traditional treatments that research has proven ineffective, likely due to confirmation bias (Kazdin, 2010).

This practice limits the interventions provided to patients and prevents them from receiving the most appropriate care. The scientific method as demonstrated in publication offers a mechanism for self-correction that is not available to the practicing therapist in the clinic (Kahmi, 2011). As the push continues toward EBP and implementation science, practitioners must reevaluate their methods and may consider the research available using single subject experimental designs.

Populations with increased heterogeneity or rarity would not be viable in large group designs (Byiers et al., 2012). Therefore, direct analysis of an individual's data may prove useful in the identification of treatment effectiveness (Byiers et al., 2012; Heyvaert & Onghena, 2013), determination of usefulness in clinical settings (Kazdin, 2010), description of individual changes (Kazdin, 2010), and the inclusion of environmental variables (Byiers et al., 2012). Other strengths of single-subject designs include: exposure of the independent variable to an individual's variability, direct interpretation of the data, and contribution to the establishment of empirically validated treatments (Perdices & Tate, 2009).

Inclusion of vital design components enables strong, high-quality research results applicable to the specified individuals. Designs including multiple phases across participants allow simultaneous replication and opportunity for multiple demonstrations of effect, thus reducing threats to internal and external validity (Byiers et al., 2012; Heyvaert & Onghena, 2013; Perdices & Tate, 2009). Temporal staggering of the phases and randomization of the moments of phase change further control for internal validity confounds (Heyvaert & Onghena, 2013) by improving causal inference. Blinding of participants and examiners to the study's purpose provides additional safeguard against internal and external threats (Tate et al., 2013). Lastly, replication across participants reduces external validity threats and improves generalization (Byiers et al., 2012).

Statement of the problem

Examination of the literature specific to physical therapy, respiration, and CP predominantly yielded results regarding positioning (e.g. Littleton, Heriza, Mullens, Moerchen, & Bjornson, 2011) and airway clearance (e.g. Bilan & Poorshiri, 2013). While, there is a large amount of clinical and anecdotal information available regarding a stretch protocol to improve speech and swallowing in children with severe motor impairments, there is no literature that systematically investigates whether any manual therapy does in fact, contribute to improved speech output. Only one article has directly evaluated the role of physical therapy in addressing chest expansion and the effects of stretch on the intercostal muscles (Jerome, Passi, & Koli, 2013). The current study represents Phase 2 research to design a treatment that would enable participants with severe motor impairments, such as CP, to produce speech and language that will not only make them more effective communicators, but also improve their quality of life.

The present study aimed to determine if a manual therapy treatment protocol provided by a trained SLP would increase speech outcome measures of intensity (SPL) and duration (s) in the maximum phonation of children diagnosed with spastic CP. Secondary outcome measures included speech intelligibility and syllables per breath unit (SBU) to assess functional changes, and chest expansion and abdominal protrusion to assess ROM and structural changes.

CHAPTER 2. LITERATURE REVIEW

Due to the limited research available, the following review evaluates the need for SLPs to address structural constraints contributing to poor respiratory support for speech in children with CP and the possibility of manual therapy being the tool they use to do so. More specifically, the American Speech-Language and Hearing Association's (ASHA) position regarding SLPs treating speech-breathing disorders, typical and atypical chest wall development, the role of the rib cage in respiratory function, and physical and speech therapy treatments addressing respiratory function in patients with neuromuscular disorders will be discussed.

Respiratory Treatment Guidelines for SLPs

ASHA published "Medical Review Guidelines" to guide health plans in claim review and policy development thus influencing clinical practice activities. The guidelines indicate intervention for children with CP may include "receptive and expressive language skills, articulation, and development of the proper breath support for speech and swallowing, as well as introducing augmentative and alternative communication (AAC) systems, such as symbol charts or speech synthesizers" (p.35) (American Speech-Language-Hearing Association, 2011). Portions of the guidelines reinforce the "Code of Ethics" principles to provide patients high quality care (American Speech-Language-Hearing Association, 2010).

In addition to the Medical Review Guidelines, ASHA details a SLP's "Scope of Practice." Broad examples of using data to guide decision-making, formulating treatment plans, and collaboration with other professionals, are outlined (American Speech-Language-Hearing Association, 2007; American Speech-Language-Hearing Association, 2011). However, no specific information regarding the treatment of children with motor deficits or respiratory concerns is included. Because ASHA chooses to focus on high quality treatment, data driven

decisions, and EBP it is important for those in the research community to fill the gaps in current research to address children with motor and respiratory deficits affecting speech production.

Cerebral Palsy

CP is the leading cause of severe physical disability in children, affecting about 500,000 in the United States (Koman, Smith, & Schilt, 2004). Often, the cause is unknown; however, known causes include: birth complications, pre-maturity, trauma, intra-cranial hemorrhage, and infection. Many children with CP exhibit one or a combination of the following impairments: reduced cognition, decreased motor function, poor vision and hearing acuity, hypersensitivity to touch or pain, and gastrointestinal complications (Kriger, 2006). Spastic CP, which comprises approximately 70-80% of those cases, results from a lesion to periventricular white matter of the brain prior to age 2 and causes motoric impairment characterized by involuntary muscle activity, poor coordination, muscle weakness, and rigidity. Spasticity is a hyper-excited tonic stretch reflex that prevents the stretching of muscles and tendons which may negatively impact a patient's function, pain level, and quality of life (Kriger, 2006).

Secondary musculoskeletal complications, such as contractures and joint displacement, develop due to movement restrictions and postural abnormalities caused from spasticity, immobility, and adaptive soft tissue changes (Abdel-Hamid & Zeldin, 2013; Koman, Smith, & Schilt, 2004; Krigger, 2006). These impairments complicate the coordination and muscle weakness concerns in patients with CP (Massery, 1991). The resulting shortened muscle length and involuntary muscle contraction manifests as muscle stiffness resulting in decreased joint mobility and increased resistance to passive joint movement (Katalinic, Harvey, & Herbert, 2011; Theis et al., 2013). Interventions addressing the primary abnormalities and prevention of secondary complications may include neuromuscular electrical stimulation, serial casting,

orthotics, bracing, speech therapy, occupational therapy, physical therapy, drug therapies, orthopedic surgery, and neurosurgery (Koman et. al., 2004). The goal of these therapies are not to achieve typical function, but to increase the function with early, intensive management (Kriger, 2006).

Speech in children diagnosed with CP, often described as dysarthric, is characterized by poor intelligibility and shortened utterances due to interactions of cognition, language, and speech development (Hustad, Schueler, Schultz, and DuHadway, 2012). Dysarthria affects the motor control of the speech subsystems (Pennington, James, McNally, Pay, & McConchaie, 2009). Speech motor control deficits in children with CP have not been thoroughly studied (Lee, Hustad, & Weismer, 2014), leaving clinicians without sufficient evidence to make treatment decisions. In regards to respiratory function, children with CP have shallow, irregular breathing patterns and often speak on residual air. Their voices are lower in pitch, often are harsh or breathy, and are sometimes hypernasal (Pennington et al., 2009). Also, there a subset of children with CP have the cognition and language abilities to enable longer, more complex utterances; however, they do not have the anatomical and physiological support to enable the needed respiratory volume for those utterances (Maner, Smith, & Grayson, 2000; Smith, 2006).

Speech Breathing and CP

Hixon and Hoit (2000) stressed the importance of SLPs' examination of the speech breathing mechanism in order to better understand the patient's respiratory system, evaluate current physical status, determine prognoses, and develop treatment plans in patients with speech breathing disorders. The anatomical relationships of respiratory structures that develop as a result of decreased range of motion (ROM) and compensatory postures further suggest treatment in this population should focus on function and ROM. Additionally, Parham (2013) described

respiratory development as foundational to the production of speech-related sounds and reiterated that relying on the adult literature when making treatment decisions for a developing system is not valid.

A recent study by Lee et al. (2014) using a multiple speech subsystems approach concluded the articulatory system contributed the most to speech intelligibility. However, only articulatory, resonatory, and phonatory systems were included in the analyses. The study did not include the contributions of the respiratory system (J. Lee et al., 2014). In describing speech as a result of the integration of multiple body systems, Massery (2012) indicated respiratory function is the foundation for intelligible speech in populations with neuromuscular impairments. This fact should direct the focus of treatment because there is a high incidence of respiratory dysfunction in children diagnosed with CP, evidenced by it being the leading cause of death in this population (Jerome et al., 2013).

There is minimal literature addressing treatment of speech breathing in children with CP. As a matter of fact, there is a body of literature that describes the lack of research and the difficulties in completing research with these children in general (e.g. Butler and Darrah, 2001; Knox, 2002). Knox and colleagues (2002) reported the variation of motor disorders and ill-defined treatment methods as problematic in determining efficacy of PT in children with CP. Butler and Darrah (2001) cited lack of discrete treatment dosages, nonspecific and variable treatment procedures, inconsistent treatment conditions, large range of therapists' skill levels, and the complications of the patient's growth and maturation.

Normal Chest Wall Development

Speech is a multi-system event requiring complex coordination of the respiratory, phonatory, resonatory, and articulatory systems to produce intelligible utterances to effectively

and efficiently communicate. Although respiration is deemed the foundation of speech production, it is important to consider that breathing is the primary function of the respiratory system. Therefore if breathing is compromised, reduction or inability to participate in other activities occurs (Hodges & Gandevia, 2000).

The respiratory system's function in speech production is to provide sufficient pressure beneath the level of the vocal folds to enable their vibration thus producing sound for vowel production and air pressure for consonant production (Solomon & Charron, 1998). The chest wall composed of the rib cage, diaphragm, and pectoral muscles, moves as a unit to achieve optimum expiratory capacity (Hixon, 1973).

Rib cage structure. The ribs are elastic arches of bone that comprise the majority of the thoracic skeleton. The “true” ribs are the first seven that connect the sternum in the front of the body to the vertebrae posteriorly. Below, the rib cage transitions to the false and floating ribs. The intercostal muscles fill the space, connecting adjacent ribs. The amount of intercostal space correlates to the age and mobility of the child. Superficial rib cage muscles contribute to inspiratory force and stiffen to optimize diaphragm function. The internal rib cage muscles along with the abdominals work together to maximize expiratory force for phonation (Hixon & Hoit, 2000). The vocal folds and support structures maintain appropriate airway opening by adducting and abducting to optimize voicing, balance vocal tension and airway pressure, and stabilize thoracic pressure (Massery, 2011).

The shape, angle, and motion of the infant rib cage vary significantly from that of an adult (See Figure 1). In typical development, normal movement patterns and gravity contribute to muscular and skeletal development of the rib cage. Shape and volume changes in the thoracic cavity occur when the ribs elevate and rotate causing displacement of the sternum. The

progression of development relies on joint mobility, movement of body parts (ex. swinging arms opposite the legs when walking or crawling), and rotation of upper and lower body structures across midline. This progression includes increasing the rib-space, lengthening of the rib cage, and changing shape from triangular to rectangular as the infant matures (Massery, 1991).

Additionally, other bones and muscles comprise the chest wall unit. The sternum, thoracic vertebrae and pectoral girdle complete the skeletal components. Furthermore, scalenes, subclavius, pectoralis major, pectoralis minor, serratus anterior, levatores costarum, serratus posterior superior, and latissimus dorsi complete the inspiratory musculature. And the transverse thoracis, subcostals, serratus posterior inferior, quadratus lumborum, and latissimus dorsi complete the expiratory musculature (Hixon & Hoit, 2000).

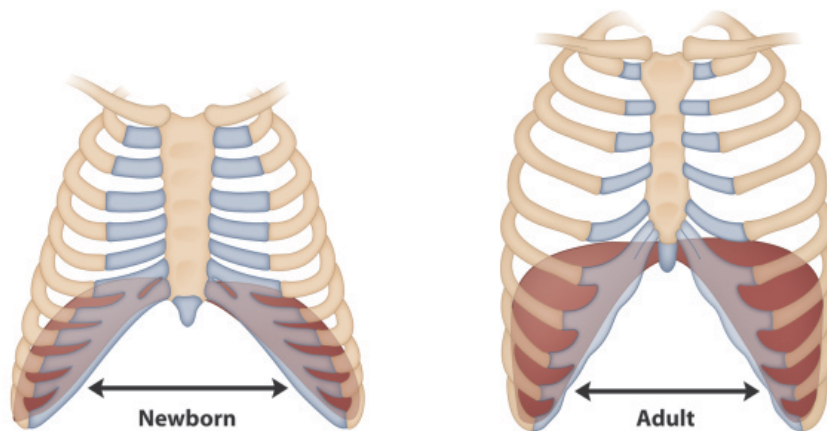


Figure 1. Illustration by Rob Fedirko. Reproduced with permission from: Litman, R. and Giles, M. Developmental Physiology and Pharmacology, in Basics of Pediatric Anesthesia, Ronald S. Litman (editor), Philadelphia, 2015. Reprinted with permission.

Rib cage function. Because a large portion of the ribs is adjacent to the lungs, Hixon (1973) concluded rib cage motion is the primary force contributing to expiratory volume. Others demonstrated this relationship by assessing the correlation between the ratios of upper to lower

chest wall measures to forced vital capacity measures. Results revealed a significant relationship between chest wall structure and respiratory efficiency (Park, Park, Rha, Park, & Park, 2006).

The superficial muscles produce inspiratory force, while deep muscles produce expiratory force. Movement of the rib cage wall relies on the mobility of the rib joints, vertebral joints, and the anterior rib articulations. The abdominals and passive recoil also contribute to both inspiratory and expiratory movements. Hixon and Hoit (2000) further stress the importance of upright body positioning in maximizing rib cage wall function.

Abdominal muscles. It is important to note the abdominal muscles additionally play an important role in respiratory function. The typical orientation of the abdominal muscles capitalize on gravity and mechanical advantage to achieve coordinated inspiratory and expiratory movements (Massery, 1991). Actions of the rib cage transport air more efficiently than abdominal motions due to its orientation to the lungs (Solomon & Charron, 1998).

Rib cage versus abdominal contributions. Studies evaluating rib cage versus abdominal contributions have systematically supported Solomon and Charron's (1998) conclusion that chest wall ROM is more valuable for speech production. Six healthy adult males with no anatomical or physiological speech deficits were studied. Displacements of the ribs, lungs, and abdomen were compared in singing, reading, and conversation conditions. Chest wall kinematic measures indicated rib cage motion is the primary force contributing to expiratory volume (Hixon, 1973). Others attempted to differentiate child versus adult kinematics in speech breathing and found similar results. Stathopoulos and Sapienza (1997) asked participants to produce the syllable /pa/. Aerodynamic and acoustic measurements were used in conjunction with kinematic measures to provide specifics regarding normal speech production in children versus adults. The data indicated approximately 82% contribution in children four to eight years

old. Hoit, Hixon, Watson, and Morgan (1990) had similar findings in participants four to fourteen years old. They assessed speech breathing in normal children in spontaneous speaking and reading conditions. Their results solidified the support that speech breathing in healthy children was produced with greater excursions than that of adults. Each of these studies provides evidence to support the focus of speech therapy on the anatomy and physiology of the rib cage to address respiratory dysfunction.

Diaphragm. Massery (2006) discussed the diaphragm is a sheet of muscle that separates the thoracic and abdominal cavities. It functions concurrently to maintain trunk control, maximize inhalation and support gastrointestinal functions. The diaphragm depends on the intercostals and abdominals to generate pressure changes between the cavities during quiet inhalation. It provides two-thirds to three-fourths of the tidal volume during quiet breathing; however, it serves a less prominent role in the controlled breathing required for speech production (Massery, 2006). Others have reported that the chest structure and abdominal structure approach more typical proportions, the diaphragm can support breathing for speech more efficiently (Druz & Sharp, 1981; Massery, 2006; Solomon & Charron, 1998). Postural, tonal, and mobility differences influence atypical development of the chest wall structure resulting in less efficient function.

Atypical Chest Wall Development

The neuromuscular and musculoskeletal systems of children with CP do not develop typically due to muscle imbalance, increased tone, decreased ROM, increased reflexes weakness, and fatigue that prevent or delay the typical developmental sequence (Koman et al., 2004; Solomon & Charron, 1998). Weak abdominal muscles and poor positioning further contribute to rib cage flaring, which inhibits respiratory mechanics including chest expansion, lung volume,

and the efficacy of the diaphragm (Massery, 1991; Solomon & Charron, 1998). Retraction of the intercostal spaces, ribs, and sternum prevent optimum lung pressures (Massery, 1991; Park et al., 2006). These musculoskeletal deviations result in a bell-shaped chest wall causing restrictive, rather than obstructive, respiratory dysfunction and a paradoxical breathing pattern (Park et al., 2006). Time spent in a flexed position increases compensatory posturing contributing to the use of additional abnormal tone (Workinger & Kent 1991). Also, an unstable rib cage forces other muscles to compensate thus preventing variety and more refined movements (Donato et al. 2008). Workinger and Kent (1991) detailed worsening vocal quality and loudness as children with CP develop due to increased use of compensatory recruitment of abnormal postures and musculature. Each of these deviations contributes to shallow inhalation and poorly coordinated exhalations resulting from immobility of the chest wall (Massery, 2006).

Hixon (1973) noted speech-breathing deviation could be the primary basis for speech deficits in many individuals with severe motor deficits. Small vital capacities have been reported in children diagnosed with spastic or athetoid CP (Hardy, 1961), suggesting shorter phonation durations (Workinger & Kent, 1991), which may impact speech intelligibility. Contributing to these breathing differences, a stiff chest wall affects the efficiency of respiration in patients diagnosed with CP (Hardy, 1961). Furthermore, Druz and Sharp (1981) described gravity as the stimulus for the stretching of human respiratory muscles and increased muscle activity, which would explain the influence of body position on ventilation and volume exchange.

Few have reported the clinical implications of deviations in chest wall structure on respiratory mechanics and efficiency. Park and colleagues (2006) compared the ratios of upper to lower chest walls in 112 children with spastic CP and 112 normally developing children, ages ranging from 32-43 months. Results indicated children with CP possess a significantly smaller

upper to lower chest ratios when compared to their typical peers point to underdevelopment of the upper chest wall. The group concluded that chronic hypoventilation, reliance on the abdominals for breath support, and paradoxical breathing patterns likely contributed to the development of inadequate chest configurations (Park et al., 2006).

Neuromotor control. The upper motor neuron damage present in children with CP results in decreased input to reticulospinal and corticospinal tracts. The neurological mechanisms and mechanical properties of muscle are altered due to upper motor neuron damage resulting in loss of function due to a decrease in the number of effective motor units, and tonal abnormalities (J. H. Carr, Shepard, & Ada, 1995; Miller, 2007). Another consequence is a loss of inhibitory input resulting in spasticity. Spasticity is an increase in muscle activity resulting in a resistance to stretch which presents as increased tone (Koman et al., 2004). It results in structural deviations in the muscle itself including a 50% reduction in muscle fiber length, fewer muscle fibers, loss of sarcomeres, and a longer tendon (see Figure 2) (J. H. Carr et al., 1995; Miller, 2007). Often spasticity develops slowly after the neurological insult and is not an immediate result of the lesion. This suggest that spasticity is an adaptation rather than a consequence of the insult, and targeting prevention of these adaptations could increase motor function insult (J. H. Carr et al., 1995).

Carr et al. (1995) attributes the clinical presentation of spasticity to both disordered motor control and soft tissue changes. They suggest that immobility is the major consequence of the brain lesion and that maintenance of soft tissue length should be maintained through active stretch and supplemented with passive stretch when active means are not possible due to the impairment.

Neuroplasticity or the brain's ability to reorganize after insult is an intrinsic property of the central nervous system (L. J. Carr, Harrison, Evans, & Stephens, 1993); however, many factors contribute to neurological reorganization in children including: age of insult, environment, intervention, type of lesion, location of lesion, and the

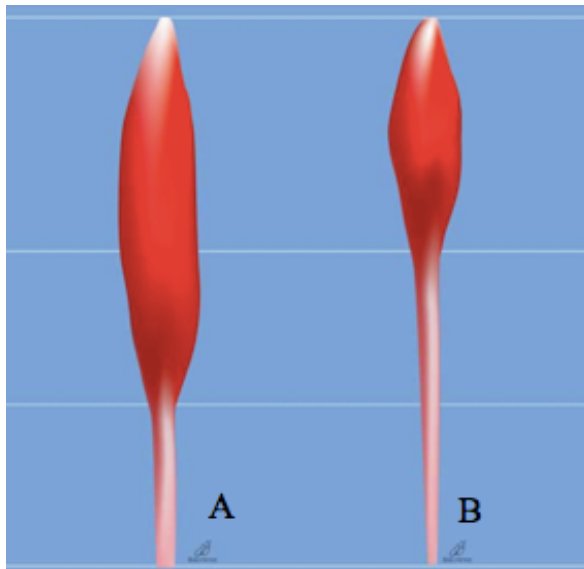


Figure 2. A-Typical muscle structure; B-Muscle structure of an individual with prolonged spasticity. From *Cerebral Palsy* (p.106), by Miller, F., 2007, New York, NY: Springer Science and Business Media, Inc. Copyright 2005 by Springer Science+Business Media, Inc. Reprinted with permission.

presence of healthy tissue (Anderson, Spencer-Smith, & Wood, 2011). Researchers are currently using functional magnetic resonance imaging (fMRI) to determine whether structural changes occur given interventions such as constraint-induced movement therapy (e.g. Sterling et al., 2013), intensive strength training (e.g. Lee et al., 2014), and virtual reality therapy (e.g. You et al., 2005) in children with CP.

Results in the current literature are promising; however, small sample sizes, heterogeneous groups, insensitive behavioral outcome measures, and short follow-up periods preclude definitive answers. Carr et al. (1993) showed evidence of central motor pathway reorganization using electromyography (EMG) responses in 21 of 33 children diagnosed with

hemiplegic CP. They described further that the corticospinal projection from the intact hemisphere branched to innervate the motor neuron of the damaged hemisphere. You et al. (2005) measured cortical activation using fMRI and demonstrated evidence of neuroplastic changes by eliminating atypical cortical activations in children with hemiparetic CP. Another research team used fMRI on two children with hemiparetic, spastic CP to determine if an intensive strength-training regimen would show evidence of neuroplastic changes. In addition to the neurological changes documented, they found muscle size and motor function increased linearly (D. R. Lee et al., 2014).

Although limited evidence exists to indicate treatments facilitate neural reorganization in patients with CP; sufficient evidence is available to warrant further investigations. As many factors influence the continuum from plasticity to vulnerability in this complex population, Anderson et al. (2011) suggests identification of interventions to target the developing brain and the minimization of secondary complications would be most valuable to inducing behavioral change in children who have experienced neurological insults.

Treatments

Physical Therapy Treatments. SLPs have included positioning and improved respiratory function to target articulatory outcomes in treatment without empirical evidence to support their choices. In fact, the shortage of research generated by researchers in communication disorders leaves SLPs with little evidence from which to select treatments to increase respiratory support for speech production in patients with motor impairments. Solomon and Charron (1998) suggested that SLPs seeking research regarding the management of breathing difficulties in children with CP refer to the physical therapy literature.

Early on, Massery (1991), PT, recounted a case study where a patient produced two syllables per breath during the initial assessment. After 2 months of physical therapy addressing chest wall development, the patient produced eight syllables per breath. Details of the treatment were not provided; however, results indicated that PT improved speech production. The results also support the present study's hypothesis that manual therapy will increase rib cage ROM that will, in turn, lead to increased speech outcomes.

Park, Park, Rha, Park,, & Park (2006) offer evidence to support that proper intervention in the early stages of development could resolve deviations in chest wall structure thus increasing respiratory function and decreasing fatigue. Maintenance of soft tissue extensibility leads to reduced manifestation of disordered motor control and adaptive changes. The prevention of contractures are traditionally managed by PTs using stretch (Katalinic et al., 2011).

In the search for “best available evidence”, the SLP could benefit from accessing research in other disciplines. In this case, research in PT (Jerome et al., 2013; Theis et al., 2013) yields results that indicate manual therapy may support increased speech outcomes. Practitioners and researchers alike should include research in other fields to support the development of EBPs in their own fields. Other disciplines may provide valuable contributions to the literature in another field; therefore, the following will discuss physical therapy treatments that may contribute to increased speech therapy outcomes.

Neurodevelopmental Treatment. Beginning in the late 1970's and early 1980's the Bobath treatment protocol, later known as NDT, for children with CP and other motor impairments began holding a ridged adherence to normal developmental sequences to influence muscle tone and improve postural alignment by practicing specific therapeutic handling techniques (Mayston 2001 a,b; Redstone 1991). As additional information and research became available in the area

of neuroscience, their approach evolved to comply with the understanding that the impaired systems could not follow the rigid neurodevelopment sequence that had been previously practiced. Also, functional tasks and active participation became vital components of the treatment in order to ensure carry over and generalization of skills (Butler & Darrah 2001). Researchers including Redstone (1991), DeGangi & Royeen (1994), and Mueller (1972) have used this approach to address the interactions and interdependence among the physiologic subsystems of the body. Impaired sensorimotor components that are likely the result of nervous system damage include tone, postural control, reflexes, movement patterns, sensory/perception, and muscle memory (Butler & Darrah 2001). Additionally, the treatment has been shown to combat the secondary effects of contractures and other deformities (Butler & Darrah 2001).

The American Academy for CP and Developmental Medicine (AACPDMD) plays an important role in influencing clinical practices by critically appraising current evidence regarding treatment techniques and protocols for the said population. In an attempt to provide an unbiased review of the literature, it was concluded that there is currently an “absence of evidence” to support the use of NDT in children with CP and other developmental disabilities. The work’s intent was to encourage research in the area of this widely used treatment method (Butler & Darrah 2001).

Stretch. Stretch is a widely used method to prevent and/or remediate contractures in patients with CP; however, there is currently inconsistent evidence regarding its efficacy (Katalinic et al., 2011; Pin et al., 2006; Riley & Van Dyke, 2012; Theis et al., 2013). Researchers have found evidence to support the immediate, transient effects of stretch on muscle length and ROM; however, long-term benefits continue to be questionable (Bovend'Eerd et al., 2008; Riley & Van Dyke, 2012; Theis et al., 2013).

Several studies have obtained results that indicate stretch yields positive effects in children with spastic CP. One studied eight children ages 6-14 years old diagnosed with spastic CP. They received passive stretching, flexing of the ankle, in physical therapy. Stretches were applied 5 times for 20 seconds. The treatment resulted in increased muscle and tendon elongation and increased ROM. They surmised short-term muscle lengthening may lead to long-term adaptations over extended treatment in children with CP (Theis et al., 2013). Although passive stretch shows short-term benefits it is unclear if active stretch is needed to facilitate long-term results. Riley and Van Dyke (2012) reported passive and active stretch resulted in reduced stiffness. Transient effects of stretch persisted 1-2 hours; however, when stretched 15-60 seconds daily, muscle changes were maintained for 24 hours. They documented reversion to the pre-stretch state occurred 2-3% daily after stretch protocol was withdrawn. Additionally, data suggested active stretch was required to change muscle fiber length, and the ROM of the individual was contingent on daily movement experiences. Given this evidence, possibly a combination of active and passive stretch would be most beneficial to children with CP. The duration of transient effects gives the SLP a window of time to work on utterance complexity and connected speech. This study gives guidance indicating the possibilities in modifications of treatment protocols and inclusion of stretch in the patients' daily routines to possibly achieve speech and language results long-term.

Continuing to narrow the scope of research, a systematic review of seven studies evaluated the effectiveness of passive stretching in children with CP (Pin et al., 2006). This search yielded similar results as discussed previously. Evidence specific to physiotherapy for children with CP is limited, and contains substantial gaps; however, data support that stretching for longer durations improves ROM and reduces spasticity of muscles around targeted joints (Pin

et al., 2006). The authors suggested that clinicians include stretching activities and optimum positioning in daily routines to prolong the treatment effects. Pin and colleagues conclude that the body of research continues to be weak and the studies' limitations make it difficult to make recommendations regarding current practices.

In evaluating the evidence, the heterogeneity of the studies discussed should be considered. The populations, number of participants, standardization of treatments, outcome measures, and inadequate designs make it difficult to draw definitive conclusions regarding the efficacy of stretch as a treatment for individuals with neuromuscular impairments (Bovend'Eerd et al., 2008; Pin et al., 2006) because meta-analysis of the available studies is not possible. Although consistent findings regarding short-term benefits are available, current literature is unclear as to the long-term benefits of stretching on ROM, spasticity, muscle length, and functional changes in this population. Clarification would enable therapists to evaluate the benefits of incorporating manual treatment protocols into current treatment plans. Pressures from payers due to rising healthcare costs and treatment restrictions magnify the importance of streamlining treatments more than ever.

Mary Massery (2012) offers a course titled "If You Can't Breathe, You Can't Function." A portion of her protocol addresses phonation where she describes evaluation, positioning, manual techniques, verbal techniques, and carry over strategies for increasing breath support for phonation. The manual therapy techniques are of interest because they differ significantly than many speech pathology approaches. Percussion or vibration is used to provide sensory information regarding chest position, airflow, and motor planning to balance vocal fold tension and chest wall contractions. Diaphragm function is targeted using Proprioceptive Neuromuscular

Facilitation, controlled exhalation using vibration, and resistance to abdominals and intercostals (Massery 2012).

Lastly, abdominal binding (trussing), a therapy approach used to address respiratory support, has little support in research with this population; however, indirect support is available when evaluating research with adults and physical therapy. When using abdominal binding, the abdominal wall is held inward providing stability during movement. In doing so, the function of the diaphragm and rib cage is optimized producing longer utterance duration (Watson and Hixon 2001). Hoit, Banzett, and Brown (2002) reported along with respiratory benefits, abdominal binding might reduce speech effort, assist neck muscle activation, glossopharyngeal breathing, and pharyngeal and buccal speech productions. In practice, this is done in a variety of ways such as belly binding, compression garments, and other devices.

Research limitations. It is not only SLPs who have neglected to sufficiently address the treatment of children with severe motor impairments such as CP. The PT literature also describes the lack of research and the difficulties in completing research with the children with CP (Knox 2002). Furthermore, expanding the scope of research from respiration to muscle changes in children with significant motor impairments yields similar results. Knox, Evans, and Lloyd (2002) suggested the variability in current treatment approaches with ill-defined procedures and the absence of validated assessment measures make demonstrating efficacy in physical therapy challenging. A review of 37 studies for children in this population revealed the studies generally presented small sample sizes, were poorly controlled, and contained poor experimental design and analysis (Hur, 1995). Royeen and DeGangi (1992) cited the lack of rigorous research addressing the use of NDT. They reported of 19 studies evaluated a number have limited sample size, lacked suitable validated measures, and used poor research design. Finally, Butler and

Darrah (2001) cited lack of discrete treatment dosages, nonspecific and variable treatment procedures, inconsistent treatment conditions, large range of therapists' skill levels, and the complications of the patient's growth and maturation.

Speech Therapy Treatments. Often, the role of respiration in speech therapy treatments is overlooked in research. Pennington et al. (2006) indicates there is a “dearth” of research in speech-language pathology addressing respiratory function in patients with neuromuscular impairments. The literature available has included positioning, regulation of respiratory function (e.g. Pennington, Smallman, & Farrier, 2006), and breathing exercises (e.g. Fox & Boliek, 2012) to target speech intelligibility. Others have chosen to address poor intelligibility by implementing augmentative, alternative, and supplementation communication strategies to provide cues to the listener (e.g. Hustad & Cahill, 2003; Hustad, Jones, & Dailey, 2003). Although there is some evidence to support each of these methods, they do not directly address the foundation of the speech problem, respiration due to ROM or muscle weakness of the chest wall.

Lee Silverman Voice Treatment LOUD. Lee Silverman Voice Treatment (LSVT) LOUD is a frequently utilized program intended to address respiratory and phonatory effort in patients with neuromuscular impairments. An important aspect of this treatment approach is that its efficacy is not influenced by the patient's cognitive ability. The majority of research located addressed adults with Parkinson's disease (e.g. Fox, Eberbach, Ramig, & Sapir, 2012). Kent (2000) warns against directly implementing adult research with children as the nature and mechanisms of childhood dysarthria differ significantly from that of adults. Another researcher points to adult systems being developed prior to the loss of function where children's motor control systems continue to be developing. Additionally, the interaction of co-existing conditions

including cognition, phonological, and language further complicate the use of adult treatment protocols with children (Levy, 2014).

A study of LSVT LOUD's efficacy by Fox and Boliek (2012) followed five children, ages 5 to 7, with a medical diagnosis of spastic CP. LSVT LOUD procedures were followed 1 hour, four days a week for four weeks. The protocol included sustaining vowels, maximum frequency range, and repetition of 10 functional phrases. Time was also spent progressing from production of single words to conversational speech. Two chi-square tests were used to assess the preferred speech samples in baseline versus posttest versus normal participants and baseline versus posttest versus follow up. For children with less output, incremental steps were taken based on baseline abilities. Immediately following treatment, listeners preferred speech samples compared to those of the samples obtained during baseline in areas such as pitch, quality, loudness, and articulatory precision. Maximum performance and acoustic measurements changed more consistently than the perceptual measures across participants. These results provide support for intensive voice treatment to improve facets of vocal functioning (C. M. Fox & Boliek, 2012).

Speech Systems Intelligibility Treatment. Systematic research has been completed evaluating the efficacy of Speech Systems Intelligibility Treatment (Pennington, Miller, Robson, & Steen, 2010; Pennington et al., 2013; Pennington et al., 2006). The treatment protocol includes three to five 30 to 45 minute sessions of individual therapy for four to six weeks. In each treatment session, coordination of phonation onset with exhalation and spoken language tasks are practiced. Motor learning principles including frequent practice, random practice, and frequent feedback are implemented during skill acquisition. The use of reduced feedback, knowledge of results, and knowledge of performance are employed to facilitate skill retention.

Results support the positive effects of motor learning activities. In one study, four of six children ages 10 to 18 years showed an immediate increase in single word intelligibility; however, significant increases were not documented in connected speech (Pennington et al. 2006). A second study looking at sixteen older children, 12-18 years old, utilizing the same protocol found increases in single word intelligibility with familiar listeners 14.7% and 15% with unfamiliar listeners. Additionally, increases were documented in connected speech to be 12.1% with familiar listeners and 15.9% with unfamiliar listeners (Pennington et al., 2010). Most recently, a study extended the age range to target younger children ages 5-11 years old. Results found speech intelligibility to increase after the protocol to 10.8% with familiar listeners and 9.3% with unfamiliar listeners in single words. In connected speech intelligibility increased 9.4% with familiar listeners and 10.5% with unfamiliar listeners. Single word intelligibility in each of these studies was obtained using Children's Speech Intelligibility Measure (Wilcox & Morris, 1999). Each child repeated 50 words taken from a 200-word list. Listeners indicated the word they heard from 10 phonetically similar words. Each study also obtained speech samples to evaluate intelligibility in connected speech by asking the children to describe a sequence of three pictures.

In addition, the authors used the Focus on the Outcomes of Communication Under Six (Thomas-Stonell, Oddson, Robertson, Walker, & Rosenbaum, 2012) to assess participation in communicative interactions. Results indicated a mean increase of 30.3 in the parent-reported measure and 28.25 in the teacher-reported measure (Pennington et al., 2013).

Manual therapy. Solomon & Charron (1998) completed a review of the literature regarding treatment of speech breathing in children with CP. After extensive research, they stated they were unable to locate efficacy studies regarding treatment influences on breathing for

speech. They concluded activities targeting muscle strength, endurance, muscle relaxation, passive stretch, balanced activity of muscle groups, and motor coordination were viable treatment options to research.

A Phase 1, single-subject design study implemented a manual therapy protocol on a 4-year-old ambulatory child diagnosed with CP (Varnado, Donovan, & Gonsoulin, 2014). Improvements in loudness measures were evidenced by a large effect size ($d=4.0$) from pre- to posttest and maintained a moderate effect ($d=0.5$) after three weeks of treatment withdrawal. Improvements in duration measures were evidenced by a large effect size ($d=7.6$) from pre- to posttest and fell to no effect ($d=.05$) after three weeks of treatment withdrawal. Additionally, increases were noted in both speech intelligibility (48% to 81%) and mean length of utterance (1.76 to 2.6) after three weeks of treatment withdrawal. Structural anatomical changes were visible by both the PT and SLP; however, measurements were not taken. Additionally, parental and service provider reports indicated increased vocalizations and oral participation in center-based and home activities. Results support the need for further research addressing the use of a manual therapy protocol in participants with severe motor impairments to influence speech outcomes, including sound pressure level and duration of phonation (Varnado et al., 2014).

SPL and MPD are often used in voice assessments to determine neuromuscular control of voice features (Cielo & Cappellari, 2008; Rvachew, Hodge, & Ohberg, 2005). They are also used to track treatment progress in children with voice disorders (Rvachew et al., 2005). The majority of normative data available for these measures are for adults and children 6 and older.

Normative data present in the literature for MPD contain large variability and often does not incorporate age, size, or height which influence lung volume (Kent, Kent, & Rosenbek, 1987). Several studies disagree on specific age level expectations for MPD and chose to group

several age groups together. Kent, Kent, and Rosenbek (1987) and Cielo and Cappellari (2008) published results that provided age ranges for children 4 to 6 years old for phonation of /a/. For our purposes, only the means of MPD of /a/ for each age are included in Table 1 below.

Table 1. Means of Maximum Phonation Time by Age

Source	4 years	5 years	6 years
Cielo & Cappellari (2008)	5.77*	7.16*	10.32*
Kent, Kent, & Rosenbek (1987)	9.00*	10.00*	13.00*

Note. *Measured in seconds (s). (Cielo & Cappellari, 2008; Kent et al., 1987).

The literature examining normative data for SPL are inconsistent in both the methods and results; therefore, using SPL to compare to aged-matched peers is currently not possible. Each study utilizes different microphone to mouth distance, which prevent standardization across studies (Kent et al., 1987). This is also the case for other maximum performance measures (Kent et al., 1987); therefore, the use of the participant as his own control enables determination of therapy progress.

In conclusion, many believe that the increasing numbers of clinical results and mounting evidence reveal the positive impact of focusing on breathing for speech intelligibility. There are mixed reviews regarding the efficacy of treatment approaches to address respiration in children with severe motor deficits. However, the body of research as mentioned earlier is incomplete and insufficient. Possible therapies include passive stretching, electrical stimulation, expiration with resistance, LSVT LOUD, NDT, posture modifications, speaking at the beginning exhalation, and marking stress, abdominal strengthening, torso-extension stretch, relaxation, abdominal binding, and balanced activity of muscle groups. A wide range of intensities and durations has been documented to provide positive change. Therapy sessions ranged from 15 minutes to an hour, two to 4 times weekly. Two studies reported a parental education and home practice component.

Considerations for cognition, fatigue, other diagnoses, and seizure activity were inconsistently reported.

Poor rib cage mobility, present in children with spastic CP, inhibits the production of audible and intelligible speech. This study aims to address the limitations of current research by assessing the efficacy of a treatment protocol that addresses structural constraints of the rib cage, while meeting the intensity restrictions imposed on practitioners by payers.

Research Questions

- What are the treatment effects of a manual therapy protocol on speech outcomes, intensity (dB SPL) and duration (s), in children diagnosed with spastic CP?
- What are the effects of the protocol on functional communication (speech intelligibility and SBU)?
- What are the effects of the protocol on the mobility of the rib cage (chest expansion) and on abdominal protrusion?

Hypotheses

Current literature led to the following hypotheses:

- Accelerating trajectory change of sound pressure level (dB SPL) and duration of phonation (s) will occur upon initiation of manual therapy protocol. Upon withdrawal of the treatment, the trajectory of the primary outcome measures will return toward baseline measures.
- Both speech intelligibility measures and SBU will increase during each treatment phase and decline during each withdrawal phase.

- The difference in rib cage circumference at each location will increase after treatment is initiated and decrease upon withdrawal. Abdominal protrusion will decrease after treatment is initiated and increase upon treatment withdrawal.

CHAPTER 3. METHODS

Design

The following, Phase 2 study was a partial replication of Varnado, Donovan, and Gonsoulin (2014) that utilized a withdrawal, single-subject (ABAB) experimental design, across participants. This design was chosen for its high degree of experimental control and the possibility of eliciting multiple demonstrations of effect. Byiers (2012) indicated this design is the strongest design to demonstrate treatment effect. Ethical considerations regarding the withdrawal of an effective treatment should be noted. The design concluded with a treatment phase and the ongoing therapist was trained to continue the treatment protocol. The Risk of Bias in N-of-1 Trials (RoBiNT) Scale (Tate et al., 2013), an instrument designed to assess quality in single-case experimental designs, was used to ensure adequate measures are taken to achieve maximum research design quality and experimental control. See Appendix A for a list of the scale's items and Table 1 for an outline of the design phases.

Before initiation of subject selection, acquisition of informed consent, child assent, collection of data, and implementation of treatment protocol, Louisiana State University's Institutional Review Board for the protection of human subjects approved the study proposal (see Appendix B).

Participants

Five participants, ages 4-6 years, were selected from the population of children with spastic CP in local educational settings. No compensation was provided to study participants for involvement in this study. Parents provided informed consent (see Appendix C) prior to initiation of study procedures.

Inclusion criteria included: adequate hearing evidenced by ability to participate in testing, aided or unaided; \geq Level 2 on the Gross Motor Function Classification System (Palisano et al., 2012); medical diagnosis of spastic CP. Exclusion criteria included: previous surgical treatment or currently medicated for spasticity; active seizure activity, uncontrolled asthma, significant scoliosis as to effect respiratory function, additional medical concern that would prevent application of treatment protocol; inability to follow simple directions to complete the treatment as reported by ongoing therapists.

To further describe the participants, the Clinical Evaluation of Language Fundamentals (CELF) Preschool -2 was administered prior to data collection (Wiig, Secord, & Semel, 2004). Additionally, each participant was classified utilizing the Communication Function Classification System (CFCS) for Individuals with CP (Hidecker et al., 2011) by the PI. See descriptions of each level in Appendix F.

Treatment Setting

Treatment took place in standard therapy rooms and classrooms with minimal distractions. Distractors were removed from the child's view. Participants watched a video of their choosing during the administration of the protocol to ensure compliance and reinforce participation. At the conclusion of each session the participant was allowed to choose a prize for participation. Items were chosen based on each participant's cognitive status, preferences, and motor abilities.

Investigators

The investigator, a certified SLP, with 13 years of experience in pediatric speech and language rehabilitation, completed the protocol procedures, obtained chest and abdominal measurements, and collected speech samples. Speech pathology undergraduate students blind to

the study's purpose and phase assisted the investigator. Following training from the investigator, the assistants collected intensity and duration data to control for investigator bias. To ensure measurement fidelity, the investigator observed 100% of the sessions to ensure procedures were followed. To ensure treatment fidelity, the assistants observed 50% of the treatment sessions. A binary choice (+/-) checklist was completed indicating compliance with procedures for both measurement and treatment fidelity checks (see Appendix G and H). Three additional speech pathology undergraduate students unfamiliar with the participants and motor speech disorders transcribed the speech sample recordings as described below for later analysis.

Equipment

Speech sample recordings were collected using an Olympus Imaging Corporation DS-20 digital voice recorder. Digital files were saved to a Dell desktop computer. Duration and SBU data were analyzed using PRAAT computer software (Boersma & Weenick, 2002) following procedures described by van Lieshout (2003). The procedure includes making a speech object from the long sound file and using both the spectrogram representation and the corresponding audio files to accurately measure each variable. Furthermore, the Audacity (2015) software version 3.0 was used to edit the sound files for intelligibility transcriptions and counting of SBU.

A Larson Davis DSP82 (Participants 1 and 2) and Extech Instruments 407732 (Participants 3, 4, and 5) sound pressure level meters with fast, C weighting were used to measure the intensity of the acoustic signal. The microphone was held six inches from the participant's mouth. This distance was maintained by adding a six-inch extension that did not obstruct the microphone. Each device was calibrated to conform to American National Standards Institute (ANSI) standards prior to data collection. Lastly, one standard tape measure was used to take all chest and abdomen circumference measurements.

Procedures

Baseline Phase (A₁). Five measurements of SPL and MPD of /a/ were collected for five sessions. During this phase, steps were taken to help the participant understand the directions. After the prompt and model were provided, the research assistant and the participant practiced the vocalization together. If measurements were within 2 standard deviations of the mean and the data trajectory was stable or decelerating, the participant began the treatment phase. If the stable baseline measurements were not present, the baseline phase would have been extended until criteria were met. Extension of baseline measures to achieve stability was not needed in these cases.

Treatment Phases (B₁ and B₂). The treatment was applied for five sessions for 15 minutes. It was the goal to complete each phase in a given week; however, if the data or absences altered the number of sessions in a given week, the number of sessions served as the criteria for moving to the next phase. Primary outcome measures were collected during each session. All other treatments were continued at recommended dosages, due to the medical needs of the participants in the targeted population and to address any possibility of treatment interaction. Tasks were counter-balanced as to prevent order effect. See Appendix I for randomization of tasks for each participant. The treatment protocol included:

1. Anterior Intercostal Stretch: The patient sat facing away from the therapist straddling a large bolster. The therapist reached around the patient and using the pads of the middle fingers applied pressure to the intercostals in first rib space beginning at sternum and moving laterally. Pressure duration was sufficient to achieve muscle release. The stretch was repeated in each rib space moving down the chest wall.

2. Posterior Intercostal Stretch: The patient sat facing the therapist straddling therapist's torso on a large bolster. The patient rested into the therapist's hands, leaning back. The therapist reached around the patient and using the pads of the middle fingers applied pressure to intercostals in first rib space beginning at vertebrae and moving laterally. Pressure and duration were sufficient to achieve muscle release. The stretch was repeated in each rib space moving down the posterior rib cage.
3. Lateral Intercostal Stretch: The patient sat away from the therapist on the bolster. The therapist formed an "L"-shape with pointer finger and thumb and placing the angle formed in highest rib space that could be reached on the lateral chest wall under the armpit. The therapist rolled the patient into the angle formed by the hand. The participant's opposite arm was raised by the same side ear. The participant was instructed to "Reach." in the direction of the stretch. Pressure and duration were sufficient to achieve muscle release. The stretch was repeated in each rib space moving down the rib cage. This series was completed bilaterally.
4. Bolster Stretch: Patient lied on their side across a large bolster. Therapist formed an "L"-shape with the pointer finger and thumb and placed the angle formed in highest rib space that could be reached on the lateral chest wall under the armpit. The participant's opposite arm was raised by the same side ear. The participant was instructed to "Reach." in the direction of the stretch. Pressure and duration were sufficient to achieve muscle release. The stretch was repeated in each rib space moving down the rib cage. This series was completed bilaterally.

5. Intercostal Percussion: The patient sat facing away from the therapist straddling a large bolster. The therapist formed an “L”-shape with the pointer finger and thumb and placed the angle formed in the highest rib space that could be reached on the lateral chest wall under the armpit on both sides. Therapist prompted and modeled, “Take a deep breath in, and push all the air out.” As the patient exhales, therapist shook and pulled down on the rib space until exhale is complete. Percussion was repeated in each rib space moving down the rib cage.

To ensure treatment fidelity, two undergraduate students observed 50% of the treatment sessions. A binary choice (+/-) checklist was completed indicating compliance with procedures for each task. A percentage was calculated to quantify the degree of compliance with task procedures.

Withdrawal Phase (A₂). A sham treatment was implemented for five sessions for 15 minutes each day. Primary outcome measures were collected during the five sessions. All other treatments continued at recommended dosage, due to the medical needs of the participants in the targeted population and to address any possibility of treatment interaction. Tasks were counter-balanced as to prevent order effect. For participants who exhibit upper limb paralysis or paresis, the therapist augmented the stretches. The sham treatment included:

1. Lateral Neck Stretch: The patient sat in an upright position. Therapist prompted and modeled, “tilt your head to the left/right”. Each stretch was held for 20 seconds and completed bilaterally 5 times.
2. Posterior Neck Stretch: The patient sat in an upright position. Therapist prompted and modeled, “bring your chin down toward your chest”. Each stretch was held for 20 seconds 5 times.

3. Forearm Stretch: The patient was seated in an upright position. Therapist prompted and modeled, “hold your arm out in front of your body, turn the palm of your hand toward the floor, and hold your fingers with the other hand.” Each stretch was held for 20 seconds and completed bilaterally 5 times.
4. Wrist Stretch: The patient sat in an upright position. Therapist prompted and modeled, “hold your arm out in front of your body, turn the palm of your hand toward the ceiling, and hold your fingers with your other hand”. Each stretch was held for 20 seconds and completed bilaterally 5 times.

Data Collection

Primary outcomes. Data collection of primary outcome measures occurred during the baseline phase (A_1) and immediately after each treatment session. Measurements of dependent variables were collected utilizing the following procedures given the prompt, “Say “ah” as loud as you can and as long as you can.” A model was also provided.

1. Sound pressure level: the sound level meter was held 6 inches from the participants’ mouths as the participant responds to the prompt. Output was measured and recorded in decibels (dB SPL).
2. MPD of /a/: the digitally recorded data were analyzed in PRAAT (Boersma & Weenick, 2002) and the number of seconds of phonation was measured and documented in seconds (s). Duration measurement procedures followed that described in van Lieshout (2003).

Secondary Outcome Measures. Secondary outcomes were administered at baseline and at the conclusion of each phase. Ten sentences randomly generated from the list of 5 word sentences from the Assessment for Intelligibility of Dysarthric Speech (Yorkston & Beukelman,

1981) were used for each measurement. This instrument's high validity and reliability was believed to provide accurate representation of the participants' abilities. Procedures of the assessment were otherwise followed to obtain the speech samples. Research assistants unfamiliar with the participants analyzed the recordings at a later date.

1. Speech intelligibility: Three speech-pathology students who were unfamiliar with the participants and have had no clinical experience with motor speech disorders transcribed the recorded samples. They were instructed to listen to each utterance two times then transcribe the utterance orthographically. The number of correct words was divided by the total number of words to obtain a percent speech intelligibility score according to methods described in the Assessment for Intelligibility of Dysarthric Speech (Yorkston & Beukelman, 1981). The listeners were blinded to the phase of the study.
2. SBU: The recordings used for intelligibility analysis were further analyzed to determine the mean number of SBUs for each sample. The number of syllables were counted and recorded. The mean was calculated by dividing the sum of the number of syllables in each utterance by the total number of utterances in each phase.
3. Chest expansion: Procedures defined by Jerome, Passi, and Koli (2013) were followed to document chest expansion. Circumference measurements were taken at the maximum inspiratory and expiratory positions of the rib cage at three locations: at the axilla, nipple, and the tip of the xyphoid process. Three attempts were averaged for each position.

4. Abdominal Circumference: The circumference of the abdomen was taken at the level of the waist. The participant stood upright if physically possible. For participants who were unable to stand or access a stander, the measurement was taken in their typical seating apparatus (i.e. wheelchair).

Table 2. Design Phases

Phase	Baseline (A ₁)	Treatment (B ₁)	Sham (A ₂)	Treatment (B ₂)
Duration	1 Week	1 Week	1 Week	1 Week
Action	No Treatment	Manual Therapy	Sham Stretch	Manual Therapy
Daily	Intensity	Intensity	Intensity	Intensity
Measures	Duration	Duration	Duration	Duration
One Time Measure	Intelligibility	Intelligibility	Intelligibility	Intelligibility
	SBU	SBU	SBU	SBU
	Chest Expansion	Chest Expansion	Chest Expansion	Chest Expansion
	Abdominal	Abdominal	Abdominal	Abdominal
	Protrusion	Protrusion	Protrusion	Protrusion

Data Analysis

Three undergraduate speech therapy students unfamiliar with the study's purpose visually inspected graphed data. Trend, level, and variability of the data in a given phase and comparisons of the adjacent phases were evaluated to locate demonstrations of effect (Kratochwill et al., 2010; McReynolds & Kearns, 1983). The immediacy of the effect, % of NOD data, and consistency of the data patterns across phases were documented (Kratochwill et al., 2010; Tate et al., 2013). Effect sizes were calculated using accepted methodology by dividing standard mean difference by the standard deviation (Busk & Serlin, 1992). Because no treatment studies have been reported in this area, data were interpreted using Cohen's *d* descriptions (0.2 indicates small effect, 0.5 indicates moderate effect, 0.8 indicates large effect) (Cohen, 1988). The raw data are included in Appendices J through N to as recommended by Durlak (2009) preventing the loss of information and allowing the research consumer to evaluate the results in context. This practice will further assist in the selection of the most appropriate treatment for patients. The secondary

outcome measures of speech intelligibility, SBU, and chest expansion were analyzed descriptively.

Treatment and Measurement Fidelity

Undergraduate students through observation completed a checklist of indicators for each task to ensure treatment fidelity. The observer designated “COMPLY” or “DID NOT COMPLY” for 5 indicators for each task. For each participant, 5 of 10 treatment sessions were observed. This exceeds the 20 percent required for each participant deemed necessary by Kratochwill et. al. (2010). 100% compliance was maintained for each participant.

To ensure measurement fidelity of SPL measurements, undergraduate research assistants unfamiliar with the study’s phase or purpose collected the primary outcome measurements. The PI was present to ensure all procedures were followed. A checklist of five indicators for the measurement was completed for 5 of 20 sessions, which equates to 20 percent of data collection sessions as suggested by Kratochwill et al. (2010). The MPD was recorded and analyzed later utilizing PRAAT software to extract duration of measures in seconds (s). Two undergraduate research assistants without knowledge of treatment phase checked each measurement. Pearson product-moment correlations were computed to determine interrater reliability of MPD measurements. SPSS version 22 was used to calculate correlation.

As noted earlier, three speech-pathology students who were unfamiliar with the participants and have had no clinical experience with motor speech disorders transcribed the recorded speech samples. They were instructed to listen to each utterance two times then transcribe the utterance orthographically. The measurements were then averaged for a single percent intelligibility score. SPSS version 22 was used to calculate correlations. Additionally, a

research assistant double-checked 20% of SBU counts. Percentage of agreement was reported.

Lastly, all data entry was double-checked for accuracy.

CHAPTER 4. RESULTS

Sample Demographics

Five participants ages 4 to 6 years old participated in the study. Demographic information for each participant is summarized in Table 2 below. Descriptions for GMFS (Palisano et al., 2012) and CFCS (Hidecker et al., 2011) are located in Appendices E and F.

Table 3. Participant Characteristics

Participant	Age	Gender	GMFS Level	CFCS Level	Expressive Language*	Receptive Language*
1	4	M	V	III	63	75
2	4	F	IV	V	53	55
3	4	F	II	III	81	75
4	5	F	V	II	59	55
5	6	F	II	II	83	77

Note. GMFS = Gross Motor Function Scale (Palisano et al., 2012); CFCS = Communicative Function Classification System (Hidecker et al., 2011); *CELF-Preschool (2nd ed.) (Wiig et al., 2004), Standard scores with $M = 100$ and $s.d.=15$.

Participant 1. Upon visual inspection of the graphed data in Figure 3 depicting sound pressure level measurements, 3 of 3 undergraduates unfamiliar with the purpose or procedures of the study identified a decelerating baseline (A_1), accelerating trajectory in the first treatment phase (B_1), decelerating/stable trajectory in the withdrawal phase (A_2), and an accelerating trajectory in the second treatment phase (B_2). The trend, level, variability, immediacy of effect, and % of NOD for each phase is reported in Table 4. Effect sizes, also reported in Table 4, compared A_1/B_1 phases and A_2/B_2 phases. The data reveal 3 of 3 demonstrations of effect. The raw data for this participant are located in Appendix J for your reference.

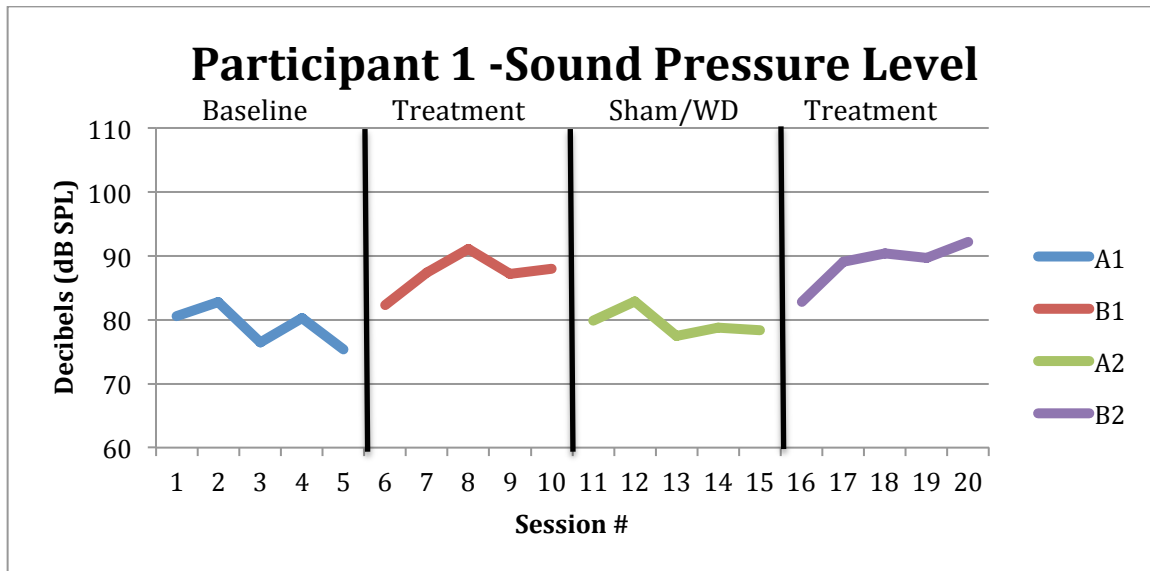


Figure 3. Means of three measures of sound pressure level obtained at the conclusion of each treatment session.

Table 4. Sound Pressure Level Analysis for Participant 1

Phase	Trend	Level	Variability	Immediacy of Effect	%of NOD	Effect Size
A ₁	-1.286	79.09	3.06			
B ₁	1.202*	87.17*	3.15*	1 st data point*	80%*	2.64*
A ₂	-.720*	79.48*	2.10*	1 st data point*	80%*	
B ₂	1.940*	88.82*	3.57*	1 st data point*	80%*	4.44*

Note. *Indicates demonstration of effect.

Visual inspection of the graphed data in Figure 4 depicting MPD of /a/ measurements indicated 3 of 3 undergraduates unfamiliar with the purpose or procedures of the study reported a descending baseline (A₁), flat trajectory in the first treatment phase (B₁), flat trajectory in the withdrawal phase (A₂), and an accelerating trajectory in the second treatment phase (B₂). The trend, level, variability, immediacy of effect, % of NOD, and consistency of data for each phase is reported in Table 5. Effect size calculations comparing A₁/B₁ and A₂/B₂ phases are reported in Table 5. The data reveals 1 of 3 demonstrations of effect. The raw data for this participant are

located in Appendix J for your reference. Table 6 depicts the means for the secondary outcome measures for Participant 1.

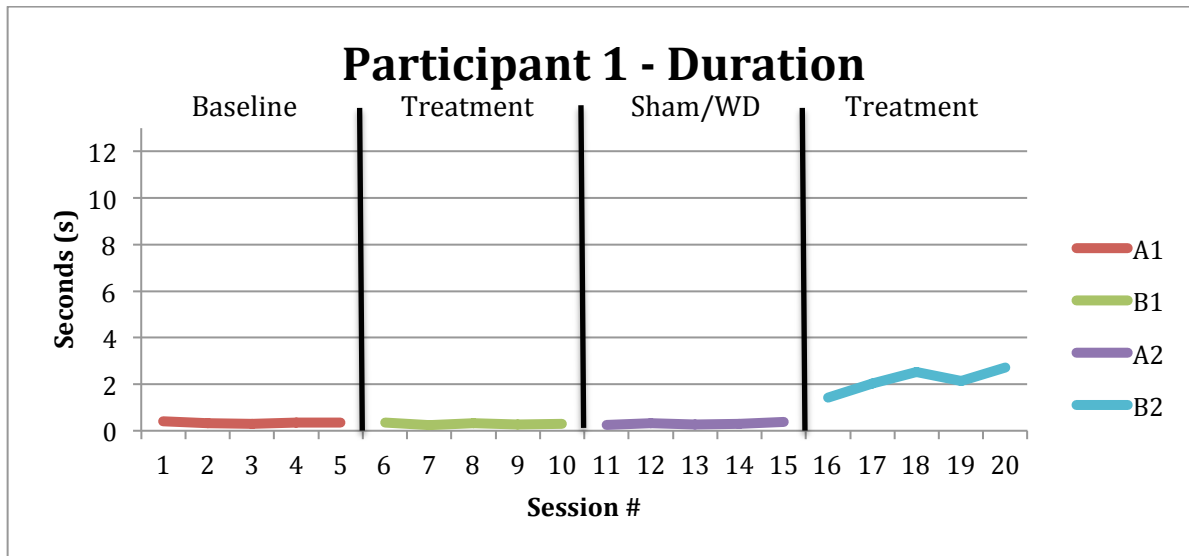


Figure 4. Means of three measures of duration obtained at the conclusion of each treatment session.

Table 5. Duration Analysis for Participant 1

Phase	Trend	Level	Variability	Immediacy of Effect	% of NOD	Effect Size
A ₁	-.02	.34	.04			
B ₁	-.04	.26	.09	none	20%	-2.00
A ₂	-.02	.27	.04	none	0%	
B ₂	.47*	1.88*	.97*	1 data point*	100%*	1.64*

Note. *Indicates demonstration of effect.

Table 6. Secondary Outcome Measures for Participant 1

Phase	Intelligibility*	SBU	\bar{X} Axilla**	\bar{X} Nipple**	\bar{X} Xyphoid**	Abdomen**
A ₁	4.67	1.0	.42	.40	.58	21.0
B ₁	12.67	2.9	.71	.98	.94	17.5
A ₂	12.67	1.8	.52	.65	.42	21.5
B ₂	16.67	2.3	.83	.77	.85	20.0

Note. *Measured in %; **Measured in inches.

Participant 2. Upon visual inspection of the graphed data in Figure 5, 3 of 3 raters reported a decelerating trajectory of baseline measures (A_1), accelerating trajectory in the first treatment phase (B_1), decelerating/stable trajectory in the withdrawal phase (A_2), and an accelerating trajectory in the second treatment phase (B_2). The trend, level, variability, immediacy of effect, % of NOD, and consistency of data for each phase is reported in Table 7. Effect size calculations comparing A_1/B_1 phases and A_2/B_2 phases are included in Table 7. The data reveal 3 of 3 demonstrations of effect. The raw data for this participant are located in Appendix K for your reference.

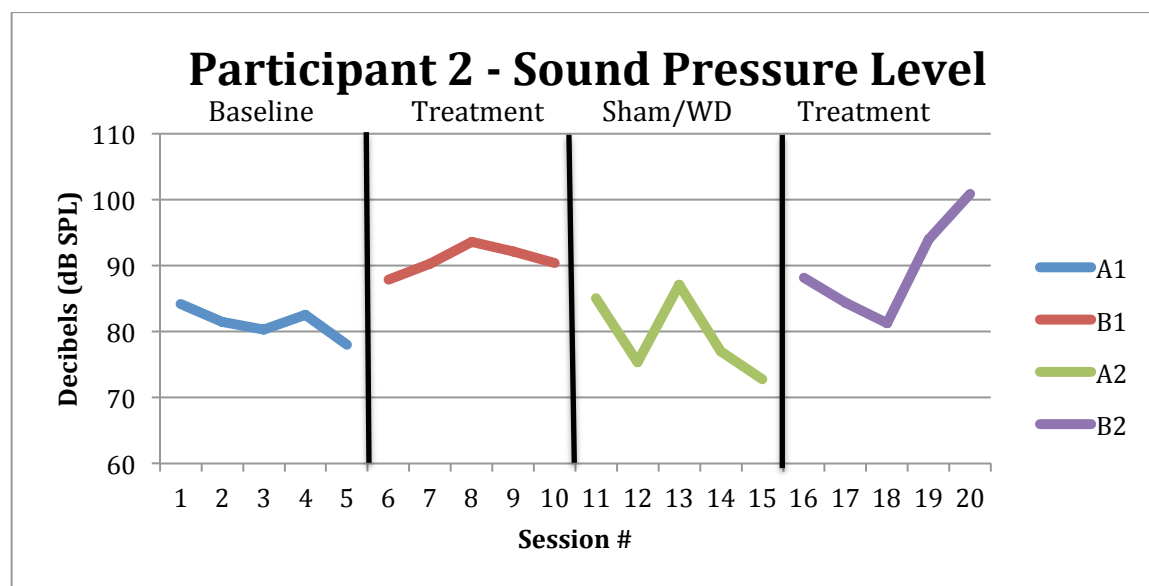


Figure 5. Means of three measures of sound pressure level obtained at the conclusion of each treatment session.

Visual inspection of the graphed data in Figure 6 depicting MPD of /a/ measurements indicated 3 of 3 undergraduates unfamiliar with the purpose or procedures of the study reported a decelerating baseline (A_1), accelerating trajectory in the first treatment phase (B_1), accelerating trajectory in the withdrawal phase (A_2), and an accelerating trajectory in the second treatment phase (B_2). The trend, level, variability, immediacy of effect, % of NOD, and consistency of data for each phase is reported in Table 8 each supporting the presence of a positive treatment effect. Effect size calculations comparing A_1/B_1 phases and A_2/B_2 phases are also located in Table 8.

The data reveal 3 of 3 demonstrations of effect. The raw data for this participant are located in Appendix K for your reference. Table 9 depicts the means for the secondary outcome measures for Participant 2.

Table 7. Sound Pressure Level Analysis for Participant 2

Phase	Trend	Level	Variability	Immediacy of Effect	% of NOD	Effect Size
A ₁	-1.12	81.31	2.33			
B ₁	.70*	90.86*	2.17*	1 st data point*	100%*	4.10
A ₂	-.15*	79.46*	6.26	1 st data point*	100%*	
B ₂	.14*	89.73*	7.83*	1 st data point*	60%*	1.64*

Note. *Indicates demonstration of effect.

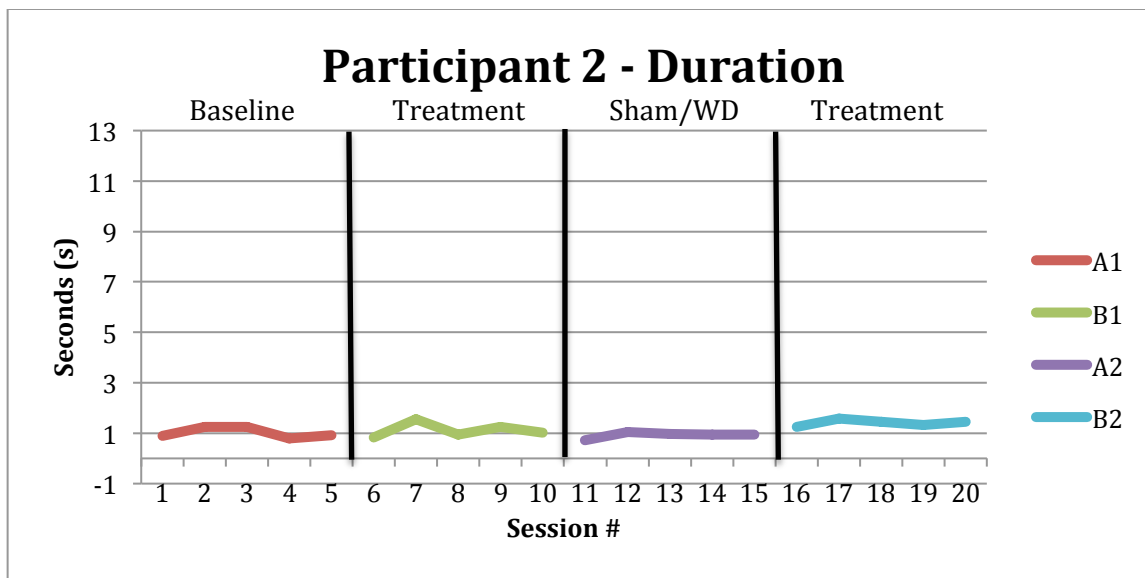


Figure 6. Means of three measures of duration obtained at the conclusion of each treatment session.

Table 8. Duration Analysis for Participant 2

Phase	Trend	Level	Variability	Immediacy of Effect	% of NOD	Effect Size
A ₁	-.15	1.02	.22			
B ₁	-.01*	1.12*	.29*	2 data points*	20%	.42*
A ₂	-.03	.92*	.12*	1 data point*	20%	
B ₂	.42*	1.14*	.10*	1 data point*	100%*	3.98*

Note. *Indicates demonstration of effect.

Table 9. Secondary Outcome Measures for Participant 2

Phase	Intelligibility*	SBU	\bar{X} Axilla**	\bar{X} Nipple**	\bar{X} Xyphoid**	Abdomen**
A ₁	1.3	3.4	.21	.52	.23	19.0
B ₁	0.0	4.2	.81	.69	1.25	19.5
A ₂	0.0	3.2	.58	.38	.54	19.0
B ₂	0.0	5.0	1.04	1.05	1.19	19.0

Note. *Measured in %; ** Measured in inches.

Participant 3. Upon visual inspection of the graphed data in Figure 7, 3 of 3 raters reported a stable baseline (A₁), accelerating trajectory in the first treatment phase (B₁), accelerating trajectory in the withdrawal phase (A₂), and an accelerating trajectory in the second treatment phase (B₂). The trend, level, variability, immediacy of effect, % of NOD, and consistency of data for each phase is reported in Table 10 each supporting the presence of a positive treatment effect. Effect size calculations comparing A₁/B₁ phases and A₂/B₂ phases indicate positive treatment effect. The data reveals 3 of 3 demonstrations of effect. The raw data for this participant are located in Appendix L for your reference.

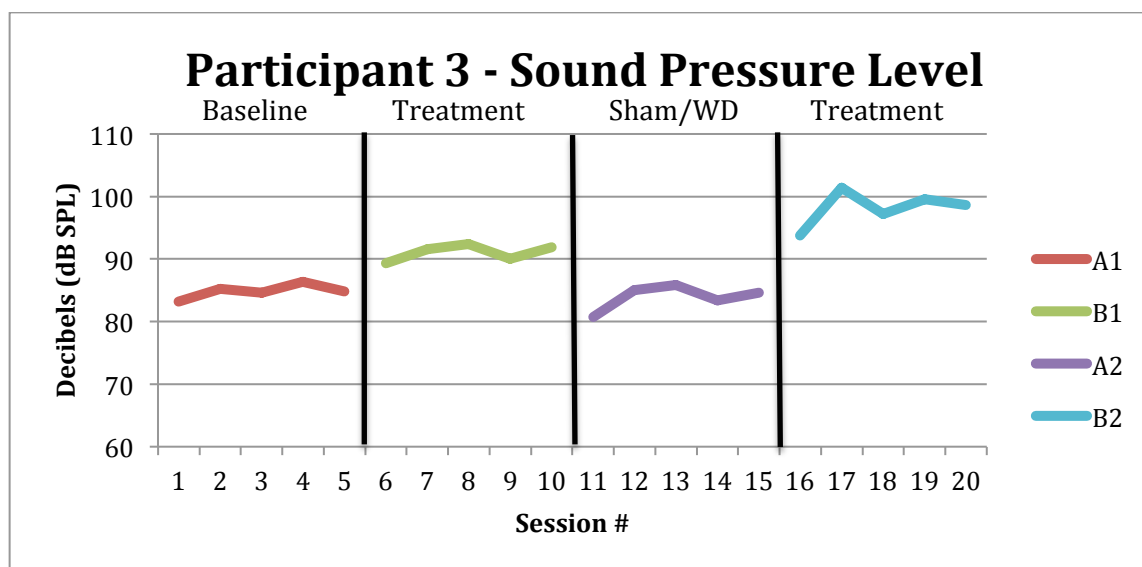


Figure 7. Means of three measures of sound pressure level obtained at the conclusion of each treatment session.

Table 10. Sound Pressure Level Analysis for Participant 3

Phase	Trend	Level	Variability	Immediacy of Effect	% of NOD	Effect Size
A ₁	.84	84.87	1.16			
B ₁	.36*	91.06*	1.31*	1 data point*	100%*	5.35*
A ₂	.61*	83.91*	1.98*	1 data point*	100%*	
B ₂	.78*	98.13*	2.88*	1 data point*	100%*	7.17*

Visual inspection of the graphed data in Figure 8 depicting MPD of /a/ measurements indicated 2 of 3 raters reported a stable/decelerating baseline (A₁), decelerating trajectory in the first treatment phase (B₁), decelerating trajectory in the withdrawal phase (A₂), and a flat trajectory in the second treatment phase (B₂). 1 of 3 undergraduates identified a flat trajectory in the first treatment phase (B₁) and agreed with the other judges of phases 1, 3, and 4. The trend, level, variability, immediacy of effect, % of NOD, and consistency of data for each phase is reported in Table 11. Effect size calculations comparing A₁/B₁ phases and A₂/B₂ phases are also reported in Table 11. The data reveals 2 of 3 demonstrations of effect. The raw data for this

participant are located in Appendix L for your reference. Table 12 depicts the means for the secondary outcome measures for Participant 3.

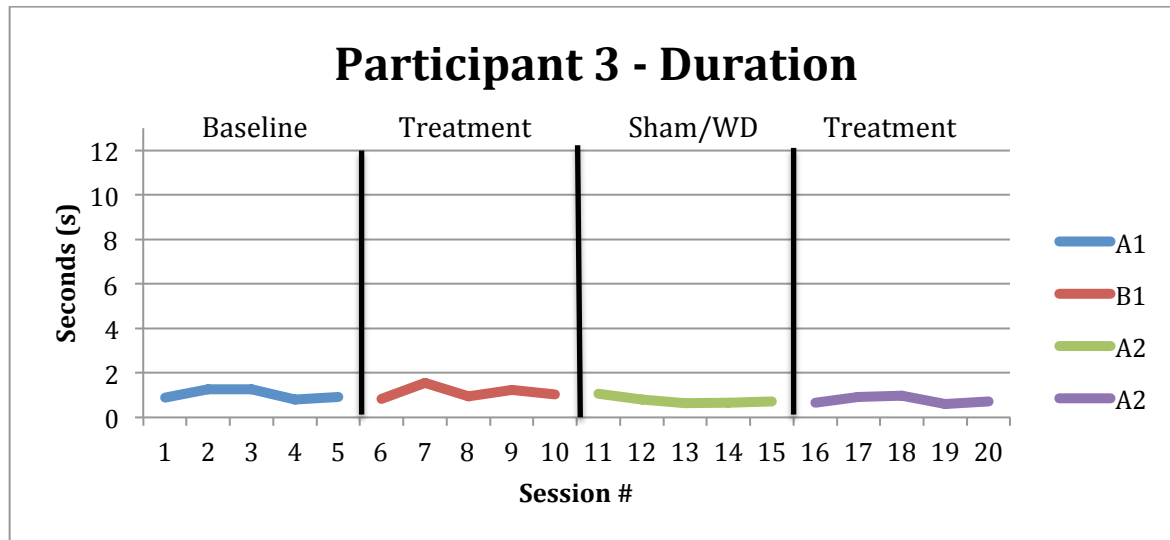


Figure 8. Means of three measures of duration obtained at the conclusion of each treatment session.

Table 11. Duration Analysis for Participant 3

Phase	Trend	Level	Variability	Immediacy of Effect	% of NOD	Effect Size
A ₁	-.15	1.02	.24			
B ₁	.01*	1.12*	.29*	2 data points*	20%	.22*
A ₂	-.08*	.78*	.17*	2 data points*	80%*	
B ₂	-.02	.77	.17	none	0%	-.06

Note. *Indicates demonstration of effect.

Table 12. Secondary Outcome Measures for Participant 3

Phase	Intelligibility*	SBU	\bar{X} Axilla**	\bar{X} Nipple**	\bar{X} Xyphoid**	Abdomen**
A ₁	14.00	3.8	.31	.33	.54	20
B ₁	15.67	4.2	.90	.75	1.02	19
A ₂	8.33	3.5	.42	.33	.56	20
B ₂	7.00	4.1	.58	.81	.62	20

Note. * Measured in %; **Measured in inches.

Participant 4. Upon visual inspection of the graphed data in Figure 9, 3 of 3 raters reported stable baseline (A_1), decelerating trajectory in the first treatment phase (B_1), accelerating trajectory in the withdrawal phase (A_2), and an accelerating trajectory in the second treatment phase (B_2). The trend, level, variability, immediacy of effect, % of NOD, and consistency of data for each phase are reported in Table 13. Effect size calculations comparing A_1/B_1 phases and A_2/B_2 phases are also reported in Table 13. The data reveal 3 of 3 demonstrations of effect. The raw data for this participant are located in Appendix M for your reference.

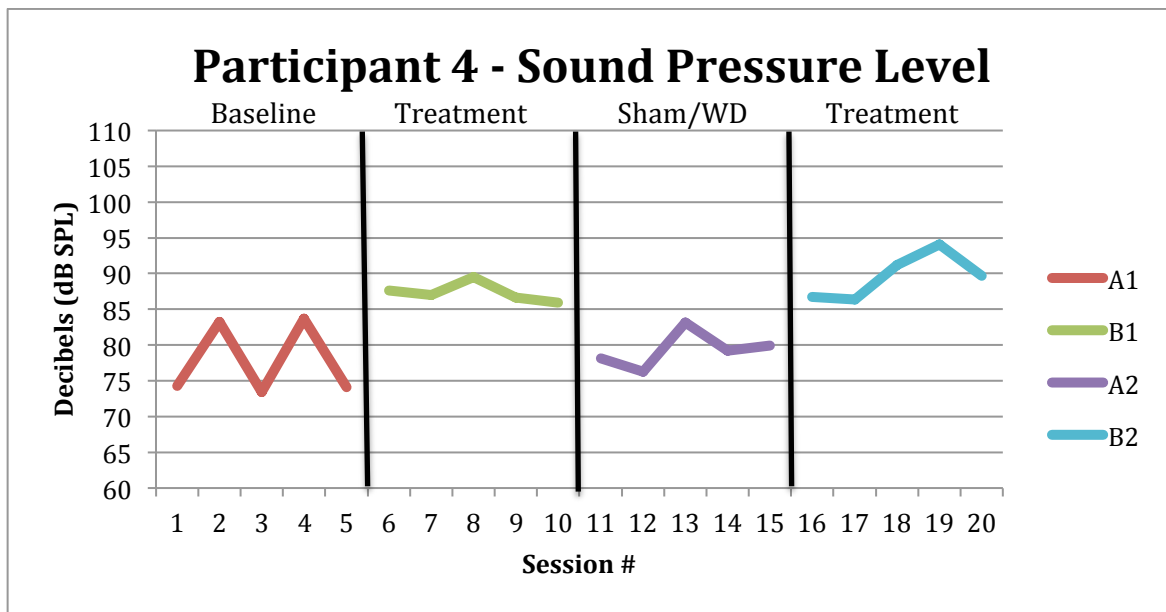


Figure 9. Means of three measures of sound pressure level obtained at the conclusion of each treatment session.

Table 13. Sound Pressure Level Analysis for Participant 4

Phase	Trend	Level	Variability	Immediacy of Effect	% of NOD	Effect Size
A ₁	.00	77.75	5.24			
B ₁	-.37	87.34*	1.37*	1 data point*	100%*	1.83*
A ₂	.65*	79.31*	2.52*	1 data point*	100%*	
B ₂	1.37*	89.62*	3.24*	1 data point*	100%*	4.07*

Note. *Indicate treatment effect.

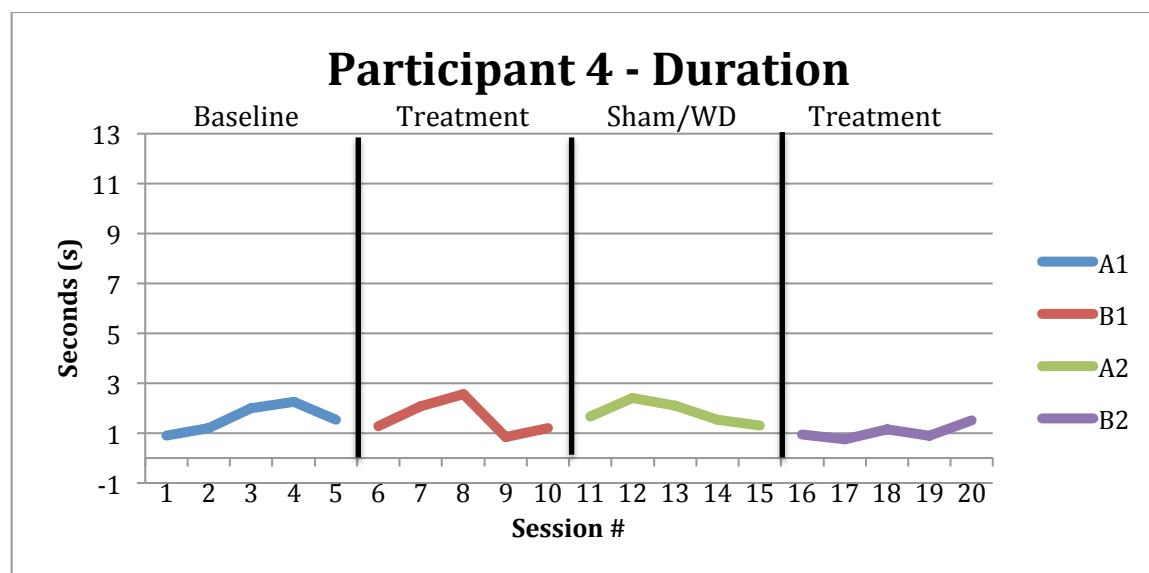


Figure 10. Means of three measures of duration obtained at the conclusion of each treatment session.

Visual inspection of the graphed data in Figure 10 depicting MPD of /a/ measurements indicated 3 of 3 raters reported a stable baseline (A₁), decelerating trajectory in the first treatment phase (B₁), decelerating trajectory in the withdrawal phase (A₂), and an accelerating trajectory in the second treatment phase (B₂). The trend, level, variability, immediacy of effect, % of NOD, and consistency of data for each phase is reported in Table 14. Effect size calculations comparing A₁/B₁ phases and A₂/B₂ phases are also reported in Table 14. The data reveal 0 of 3 demonstrations of effect. The raw data for this participant are located in Appendix L for your reference. Table 15 depicts the means for the secondary outcome measures for Participant 4.

Table 14. Analysis of Duration for Participant 4

Phase	Trend	Level	Variability	Immediacy of Effect	% of NOD	Effect Size
A ₁	.13	1.57	.56			
B ₁	-.14	1.59	.70	3 data points*	20%	.02
A ₂	-.16	1.80	.44	none	0%	
B ₂	.13*	1.05	.30	none	100%	-1.43

Note. *Indicates demonstration of effect.

Table 15. Secondary Outcome Measures for Participant 4

Phase	Intelligibility*	SBU	\bar{X} Axilla**	\bar{X} Nipple**	\bar{X} Xyphoid**	Abdomen**
A ₁	11.33	6	.17	.29	.31	21
B ₁	31.00	6.3	.67	.88	.75	20
A ₂	17.67	6.1	.19	.29	.33	21
B ₂	16.67	5.7	1.10	.79	.94	19

Note. *Measured in %; **Measured in inches.

Participant 5. Upon visual inspection of the graphed data in Figure 11, 3 of 3 undergraduates unfamiliar with the purpose or procedures of the study reported a stabilized baseline, flat trajectory in the first treatment phase (B1), decelerating trajectory in the withdrawal phase (A2), and a decelerating trajectory in the second treatment phase (B2). The trend, level, variability, immediacy of effect, % of NOD, and consistency of data for each phase is reported in Table 16. Effect size calculations comparing A₁/B₁ phases and A₂/B₂ phases are also located in Table 16. The data reveal 3 of 3 demonstrations of effect. The raw data for this participant are located in Appendix N for your reference.

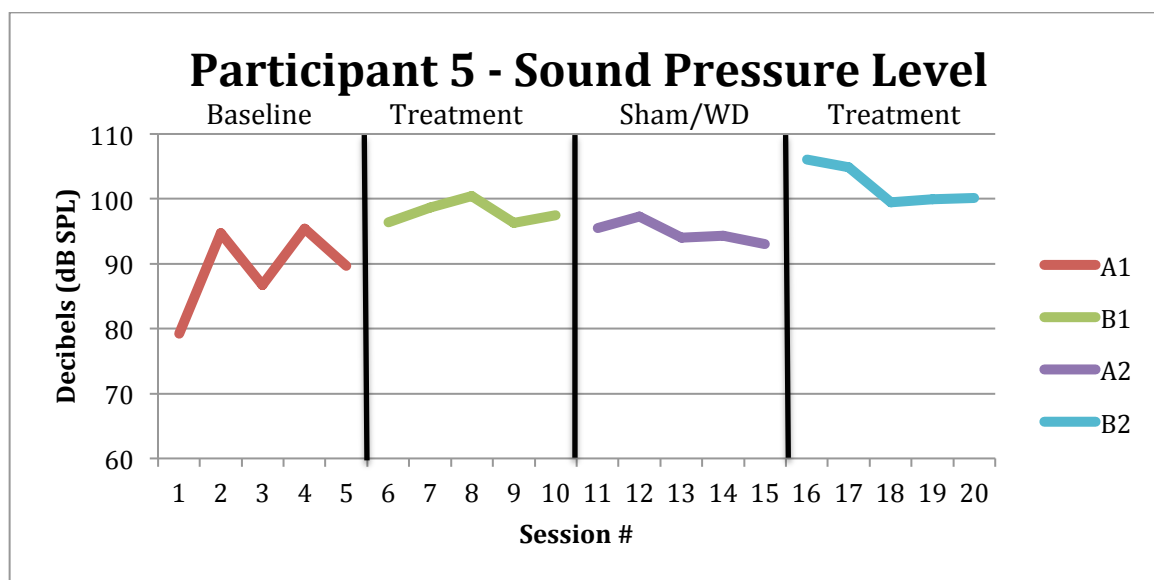


Figure 11. Means of three measures of sound pressure level obtained at the conclusion of each treatment session.

Table 16. Analysis for SPL for Participant 5

Phase	Trend	Level	Variability	Immediacy of Effect	% of NOD	Effect Size
A ₁	.12	89.14	6.60			
B ₁	-.03	97.85*	1.74*	1 data point*	100%*	1.32*
A ₂	-.80	94.82*	1.63*	1 data point*	80%*	
B ₂	-1.67	102.10	3.11*	1 data point*	100%*	4.46*

*

Note. *Indicates demonstration of effect.

Visual inspection of the graphed data in Figure 12 depicting MPD of /a/ measurements indicated 3 of 3 raters reported a stable baseline (A₁), a decelerating trajectory in the first treatment phase (B₁), accelerating trajectory in the withdrawal phase (A₂), and a decelerating trajectory in the second treatment phase (B₂). The trend, level, variability, immediacy of effect, % of NOD, and consistency of data for each phase is reported in Table 17. Effect size calculations comparing A₁/B₁ phases and A₂/B₂ phases are also located in Table 17. The data reveal 3 of 3 demonstrations of effect. The raw data for this participant are located in Appendix

N for your reference. Table 18 depicts the means for the secondary outcome measures for Participant 5.

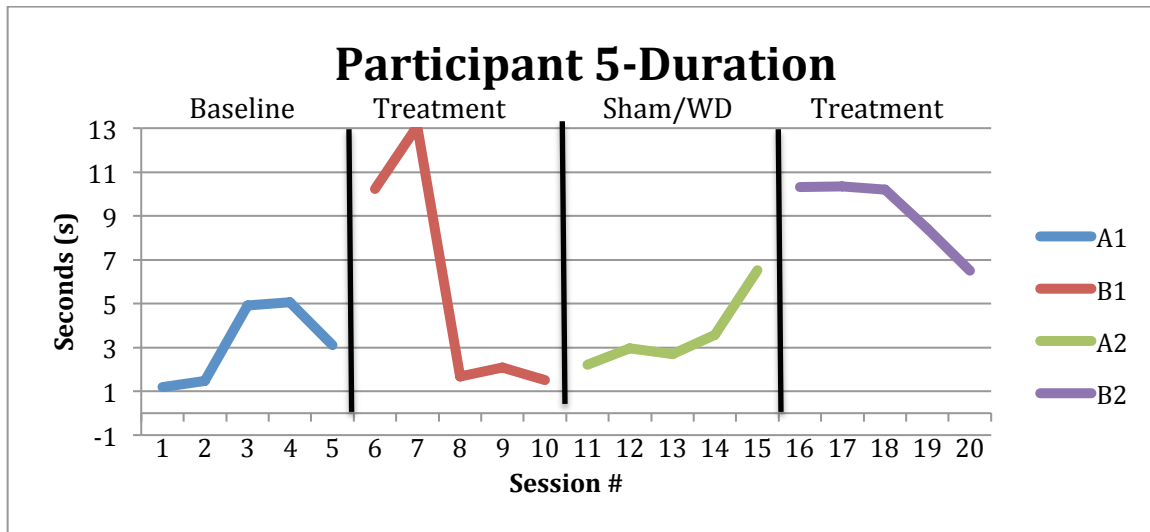


Figure 12. Means of three measures of duration obtained at the conclusion of each treatment session.

Table 17. Duration Analysis for Participant 5

Phase	Trend	Level	Variability	Immediacy of Effect	% of NOD	Effect Size
A ₁	.50	3.14	1.83			
B ₁	-2.85	5.72*	5.53	1 data point*	40%	.47*
A ₂	.79*	3.59*	1.71	none	0%	
B ₂	-.95	9.15*	1.69*	1 data point*	80%*	3.24*

Note. *Indicates demonstration of effect

Table 18. Secondary Outcome Measures for Participant 5

Phase	Intelligibility*	SBU	\bar{X} Axilla**	\bar{X} Nipple**	\bar{X} Xyphoid**	Abdomen**
A ₁	26.67	5.0	.83	.81	.42	19.00
B ₁	45.00	6.0	.75	.83	.52	19.00
A ₂	34.67	2.5	.56	.47	.44	19.63
B ₂	11.33	6.5	.94	.85	1.65	19.00

Note. *Measured in %; **Measured in inches.

Treatment and Measurement Fidelity

Undergraduate research assistants completed treatment fidelity checklists in 20% of treatment sessions. Five indicators for each task were judged. Treatment sessions observed were 100% in compliance with protocol procedures. Similarly, the PI completed measurement fidelity checklists for 20% of sessions. 100% compliance was maintained for the intensity measurement.

Reliability Measures

The primary investigator and two research assistants extracted MPD measurements from the speech sample recordings. Pearson product-moment correlations were computed using SPSS version 22. All correlations among the investigators and research assistants were statistically significant ($p \leq .001$). Strong positive correlations ($r > .90$) were found between each pair of judges. The following correlations were obtained: Judges 1 and 2 ($r = .99$), Judges 1 and 3 ($r = .98$), and Judges 2 and 3 ($r = .99$).

Question 1

What are the treatment effects of a manual therapy protocol on speech outcomes, intensity (dB) and duration (s), in children diagnosed with spastic CP?

In examining the data across participants, 15 of 15 demonstrations of effect and 0 demonstrations of non-effect were located for SPL, and 8 of 15 demonstrations of effect for MPD of /a/ were located. This data support a positive effect on speech outcome measures of SPL given a manual therapy treatment addressing spasticity. The inconsistency of MPD data provided minimal support the presence of a treatment effect given one week of treatment. The immediacy of each effect, % of NOD and consistency of data patterns across each phase for each participant further strengthen the ability to make causal inference that there was a treatment effect on SPL given the manual therapy protocol. Those measures for MPD showed inconsistent evidence of a

treatment effect. Effect sizes for SPL ranged from 1.32 to 7.17 also indicating a treatment effect, whereas, effect sizes for MPD ranged from -2 to 3.98 indicating strongly negative to strongly positive treatment effect. The inconsistencies of the MPD data are further discussed below.

Question 2

What are effects of the protocol on functional communication (speech intelligibility and SBU)?

Speech intelligibility across participants improved in 5 of 10 treatment phases and stabilized or decreased during 3 of 5 withdrawal phases. Table 19 depicts the mean intelligibility score obtained from 10, 5-word utterances examined by 3 listeners unfamiliar with motor speech disorders or the participant across participants at the conclusion of each phase.

SBU improved in 9 of 10 treatment phases and stabilized or decreased in 5 of 5 withdrawal phases. Table 20 describes the number of SBU across participants at the conclusion of each phase. The measurements were extracted from the sentence prompts used in the intelligibility measurements using PRAAT software (Boersma & Weenick, 2002).

Question 3

What are the effects of the protocol on the mobility of the rib cage (chest expansion) and on abdominal protrusion?

Measurements of rib cage circumference were used to determine whether the treatment had an effect on rib cage mobility. Results indicated that the difference in chest wall circumference from maximum inhalation to maximum exhalation increased during manual therapy treatment phases and declined during withdrawal phases. For each data point, three measurements were taken and averaged at the level of the axilla, nipple, and xyphoid process. The differences are reported in Table 21. To determine whether abdominal protrusion was reduced, the abdominal circumference at the level of the waist of each participant was measured

at the end of each phase. The measurements decreased during treatment as hypothesized in 6 of 10 opportunities and returned toward baseline during the withdrawal phase in 4 of 5 opportunities.

Table 19. Intelligibility Across Participants

Phase	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
A ₁	4.67	1.3	14.00	11.33	26.67
B ₁	12.67*	0.0	15.67*	31.00*	45.00*
A ₂	12.67	0.0	8.33*	17.67*	34.67*
B ₂	16.67*	0.0	7.00	16.67	11.45

Note. *Indicates demonstration of effect; measures are in %.

Table 20. SBU Across Participants

Phase	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
A ₁	1.0	3.4	3.8	6.0	5.0
B ₁	2.9*	4.2*	4.2*	6.3*	6.0*
A ₂	1.8*	3.2*	3.5*	6.1*	2.5*
B ₂	2.3*	5.0*	4.1*	5.7	6.5*

Note. *Indicates demonstration of effect.

Table 21. Summary of Changes in Rib Cage ROM Across Participants

Phase	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
A ₁	A= .40	A= .52	A= .31	A= .17	A= .83
	N= .42	N= .21	N= .33	N= .29	N= .81
	X= .58	X= .23	X= .54	X= .31	X= .42
	AB=21.00	AB=19.00	AB=20.00	AB= 21.00	AB=19.06
B ₁	A= .98*	A= .69*	A= .75*	A= .67*	A= .75
	N= .71*	N= .81*	N= .9*	N= .88*	N= .83*
	X= .94*	X=1.25*	X= 1.02*	X= .75*	X= .52*
	AB=17.50*	AB=19.50	AB= 19.00*	AB= 20.00*	AB= 19.00
A ₂	A= .65*	A= .38*	A= .42*	A= .19*	A= .56*
	N= .52*	N= .58*	N= .33*	N= .29*	N= .47*
	X= .65*	X= .54*	X= .56*	X= .33*	X= .44*
	AB=21.50*	AB=19.00	AB= 20.00*	AB= 21.00*	AB= 19.63*
B ₂	A= .77*	A=1.05*	A= .94*	A=1.10*	A= .94*
	N= .83*	N=1.04*	N= .81*	N=.79*	N= .85*
	X= .85*	X=1.19*	X= .63*	X=.94*	X= 1.65*
	AB=20.00*	AB=19.00	AB= 20.00	AB=19.00*	AB=19.00*

Notes. *Indicates demonstration of effect; A = axilla, N = nipple, X = xyphoid, and AB = abdominal circumference; All measurements are in inches.

CHAPTER 5. DISCUSSION

This Phase II, A-B-A-B single-subject experimental design study was replicated across five participants and used demonstrations of effect for primary and secondary outcome measures to evaluate the treatment efficacy of a manual therapy protocol on speech outcomes in children with spastic cerebral palsy. Given the heterogeneity of children with CP, the use of single-subject experimental design was used to support the development of a treatment for this population. Treatments addressing respiratory function are profoundly needed to address the foundation of the speech disorder. The known literature intended to support SLPs and researchers in making evidence-based treatment decisions are perforated with design problems including: little consistency in treatment duration, protocols and frequency.

Although current research in the area of physical therapy supports the use of manual therapy to increase rib cage ROM (e.g. Jerome et al., 2013), no research was located reflecting its impact on speech production. Given respiration is the foundation for speech production (Massery, 2012) and the rib cage contributes 84% of pressure for that process in children in this age range (Hoit, Hixon, et al., 1990; Stathopoulos & Sapienza, 1997), using the strategies employed by PTs to increase mobility of the chest wall could likely result in positive changes in the intensity and duration of phonation and possibly affect speech intelligibility and SBU. The results of the present study reveal a treatment effect in speech intensity (dB SPL) and SBU when provided one week on the manual therapy protocol. Treatment effects were not found for duration of phonation and speech intelligibility. What follows is a more in-depth discussion about the results according to each experimental question and individual results. Lastly, theoretical implications, research implications, clinical implications, and study limitations will be addressed.

Question 1

Question 1 aimed to determine the presence of treatment effects of a manual therapy protocol on speech outcomes, SPL and MPD in children diagnosed with spastic CP. I hypothesized an accelerating trajectory change of SPL and MPD would occur upon initiation of the manual therapy protocol. Upon withdrawal of the treatment, the trajectory of the primary outcome measures would return toward baseline measures. These hypotheses were based on the current literature in physical therapy and speech therapy that yields results that point to a treatment effect influencing lung volume and ROM (Jerome et al., 2013; Jones et al., 2014).

All five participants demonstrated a large treatment effect (Cohen, 1988) evidenced by change in SPL measurements and data analyses including: trend, level, variability, immediacy of effect, % of NOD, and effect sizes. MPD results were less consistent. Possible explanations for this discrepancy are discussed below.

Three possibilities for the inconsistent MPD results come to mind. First, the language abilities of the participants should be considered as many children with cerebral palsy have language deficits (Hustad, Schueler, Schultz, & DuHadway, 2012). Each participant was given the CELF Pre-School-2 (Wiig et al., 2004), and their Core Language Scores ranged from 45 to 88. All participants had below average receptive language abilities ranging from 55-77, which may have accounted for only 2 of 5 participants understanding the concept of “long”. Furthermore, receptive language deficits may have prevented Participants 1, 2, and 3 from understanding and following the 2-part prompt, “Say/a/ as loud and long as you can.” In future studies the ability to follow two-step commands and the receptive knowledge of the concept “long” could be added to the inclusion criteria.

A second possibility for MPD inconsistencies may have to do with treatment duration. In the pilot study, the participant received 6 weeks of manual therapy, which elicited improvements in MPD (Varnado et al., 2014). It is possible that changes in MPD require longer treatment duration and/or more intensive motor practice to enable the controlled release of air during exhalation. Only direct and systematic replication of the present study will resolve the present inconsistencies related to MPD.

In working with children who have lower language abilities, it might be more beneficial to change the primary outcome measure from MPD to SBU in spontaneous speech. SBU was a secondary outcome measure in this study; however, in 14 of 15 opportunities participants' numbers increased and decreased as predicted provided the administration or withdrawal of treatment. Furthermore, SBU may be a more functional measure of speech output since it can be produced at the participant's usual vocal loudness. Last, a measure of SBU could be useful, not only for children who have receptive language deficits, but also for those who are producing pre-speech vocalizations (e.g. producing jargon or babbling)

A third explanation, could be that participants need more motor practice to have the motor control required to produce longer utterances. This is supported by the variability between the first and second treatment phases for Participant 1. He did not demonstrate a change in data trajectory during the first treatment phase (B_1); however, he did so in the second treatment phase (B_2). It might be that once he was able to master the intensity portion of the task, he was able to use newly available cognitive effort or attention to be "loud and long".

Question 2

The second research question targeted the effects of the treatment protocol on functional communication (speech intelligibility and SBU). It should be the ultimate goal of speech therapy

for treatment goal achievements to translate to activities and participation in daily life (Donovan, Kendall, Young, & Rosenbek, 2008).

There is little of information available regarding how speech intelligibility and cognitive and/or linguistic levels are affected by the development and impairment present in children with severe motor impairments. The current study examined intelligibility descriptively to provide information regarding the functional communication effects of the treatment protocol and guide future studies in the examination of the dosage adequate to elicit functional communication changes. Small sample size, variation of the presentation of function in individuals with CP, and language level of each participant could have contributed to the large variability in the secondary outcomes in the current study. Furthermore, participants with higher cognition and semantic abilities would have likely performed better on the sentence repetition task. Those with reduced cognitive and language abilities likely experienced a higher cognitive load during the sentence repetition task and decreased attention to speech motor control. The sentences used in this study included more complex vocabulary and syntactic structures as the stimuli were obtained from an intelligibility test normed for ages 12 and older. Morgan, Hodge, and Pennington (2015) confirm the lack of availability of a suitable tool to assess intelligibility in connected speech in children.

The participants in the current study received 2 non-concurrent weeks of treatment did not experience a similar change in speech intelligibility as compared to the participant in the pilot study who received six weeks of treatment (Varnado et al., 2014). Definitive judgments as to why this is the case are not possible due to the comparison of only one participant in the pilot study and five participants in the current study.

Normative data were not located for SBU for children ages 4-6 years old. Hixon and Hoit (1987) reported results of healthy men; however, for many reasons this data cannot be applied to

children. In 14 of 15 opportunities, changes in SBU provided the implementation or withdrawal of treatment indicate functional communication change in these participants. Production of more words per breath unit could reduce fatigue during connected speech production. Further research including this variable in typical and disordered children may provide knowledge whether this indicator can be linked to changes in quality of life measures.

Finally, Participant 2 in the present study presented both dysarthria and apraxia. Her intelligibility measures ranged from 0 to 1.3%. Although measures of intensity and SBU indicated change, the apraxia could have contributed to the decrements in intelligibility. Further research to address dosage would help identify and explain the differences present.

Question 3

Question 3 sought to establish if the manual therapy protocol changed the mobility of the rib cage (chest expansion) and reduced abdominal protrusion. The study by Jerome et al (2013) found support that such change would occur; however, that study neither described the therapy procedures nor the speech outcomes. It was hypothesized that the difference in rib cage circumference at each location would increase after treatment was initiated and decrease upon treatment withdrawal. Furthermore, abdominal protrusion would decrease after treatment was initiated and increase upon treatment withdrawal.

In 44 of 45 opportunities, the ROM increased/decreased as treatment was provided or withdrawn as expected. These results provide further support that reduction in spasticity would allow for increased breath support for speech also strengthening the support for a positive treatment effect. This supports the Jerome et al. (2013) that demonstrated manual therapy including stretch increases rib cage ROM in children with spastic cerebral palsy. That study also found abdominal protrusion decrease upon implementation of treatment. In the present study the

circumference of the abdomen increased/decreased as treatment was provided or withdrawn in 7 of 15 opportunities. These results were not as consistent as those in the Jerome et al. (2013) study. It should be noted that the measurements of the abdomen changed as hypothesized for those participants who had more severe motor involvement. Participants 1 and 4 are wheelchair dependent and have minimal opportunity to practice the oppositional motor movements required to promote rib cage development and maintain structural changes attained in the present study. Participants 2, 3, and 5 do have movement restrictions; however, they are able to move more freely. Their rib cage development prior to the initiation of the study exceeded that of Participants 1 and 4.

In summary, the results of this study indicate a treatment effect is present affecting SPL, SBU, and rib cage ROM. No treatment effect was elicited affecting MPD and intelligibility. These results may contribute to a better theoretical understanding of the application of motor learning principles and exploiting neuroplasticity in children with spastic cerebral palsy.

Theoretical Implications

Currently, two broad areas of research that could be influenced by these results include the use of motor learning principles in speech therapy and capitalizing on neuroplasticity in speech therapy. Current treatment research in motor speech seeks to determine if implementation of motor learning principles will elicit functional change in speech outcomes (Maas & Farinella, 2012; Maas et al., 2008). Stimuli selection, practice structure, and feedback conditions has proven to increase performance and learning (e.g. Wambaugh, Nessler, Cameron, & Mauszycki, 2012, 2013; Wambaugh, Nessler, Wright, & Mauszycki, 2014). A component of these principles not addressed currently in the literature is the reduction, alteration or elimination of individual structural constraints. It is the ultimate goal of this research to determine if reducing the

movement constraints impeding the ROM of will promote functional changes resulting in increased breath support for speech production or possibly enable motor practice to occur.

Another recurring theme in the treatment of neuromotor disorders is neuroplasticity. Although neuroimaging has provided large amounts of information about injury and recovery, little has linked the brain lesions to speech outcomes in children. Anderson (2011) reported the highest phase of plasticity occurs in children ages 3 to 6 years old, describing the period of time pre-and post- as having reduced plasticity. This evidence closely parallels the “critical period” of language development discussed by Lenneberg’s Critical Period Hypothesis (1967) of language. Emphasis on this important time in development should be accounted for in further research addressing motor speech disorders, neuroplasticity and children. Combining Anderson’s contribution to Lenneberg’s points to likely the most valuable time for treatment in children with motor speech impairments. This time period should be utilized optimally to elicit maximum therapeutic outcomes.

Lastly, a high frequency of motor practice is required to elicit cortical changes (L. J. Carr et al., 1993; D. R. Lee et al., 2014). A change in individual structural constraints may be required to enable this practice, especially at the dosage required for change. The present study is a step toward discriminating the rolls of motor learning and neuroplasticity given this manual therapy protocol. The results of this study support the need for further research to address these treatment questions.

Research Implications/Future Research

There is abundant literature regarding the importance of respiratory function in the production of audible and intelligible speech (Hixon, 1973; Massery, 2012); however, minimal research exists addressing the treatment of respiratory function to affect speech outcomes in

children with severe motor impairments (Butler & Darrah, 2001; Knox & Evans, 2002). Current literature does not provide sufficient evidence to enable firm treatment recommendations resulting in the use of treatments that are not evidence-based or ideal for the patients. Variability in the population of children with CP prevent the application of large-scale randomized control trials; therefore, the use of systematic and direct replication of single-subject design studies would most contribute to the development of evidenced-based treatments (Levy, 2014).

Modifications to the methods could provide more specific information as to the effect of manual therapy treatment. Collecting sound pressure level of spontaneous speech or speech samples of preselected sentence list as the primary outcome measure in place of the MPD of /a/ would give knowledge of performance changes more directly reflecting communicative competence. Additionally, obtaining measures both before and after the treatment would help separate the transient versus residual effects of the treatment.

The complex symptomology of children with CP complicates studies such as this one. The participants in this study were identified with respiratory complications that affected speech outcomes. Two participants had personal nurses that followed them throughout their day to ensure adequate care. One of these participants was eventually excluded from the study due to extended gaps in treatment time or phase shifts due to respiratory complications that required steroid medications, hospitalizations, and other medications to improve respiratory function. Additionally, respiratory illness is common in the months of January and February (e.g. Dawson-Caswell & Muncie, 2011; Epperson et al., 2014). Some participants did participate when minor respiratory illness arose and continued to attend school. In the case of Participant 2, the other participant with a personal nurse, there is a large decelerating shift in the SPL data trajectory when she started to have a runny nose. Lastly, Participant 5 exhibited the same pattern when she

became congested in the first treatment phase (B₁). Future researchers cannot avoid these happenings; however, awareness may guide research design choices such as conducting the study in the summer and fall when respiratory illness is less active.

Extensions of this study should include groups of specific age groups (1-2 years, 3-5 years, 6-9 years, 10-15 years, and 16- adulthood). These increments were chosen based on motor and language developmental changes that separate the distinct groups. For participants in the youngest group or those with decreased or questionable levels of cognition, primary outcome variables could be modified to include the SPL of spontaneous communication attempts and number of SBU during jargon or babbling. Furthermore, other diagnoses that include spasticity should be explored including stroke, traumatic brain injury, multiple sclerosis and stroke.

Optimal dosage should be explored. Questions including at what dosage do participants plateau, what dosage is required to achieve maintenance, and what dosage is required before transitioning to a home program are each areas to be addressed. Given the current culture of minimal coverage for therapy by insurance companies, efficacy and efficiency are paramount. Answering the dosage questions will enable implementation of the most valuable treatments to achieve optimal results.

Although SPL and MPD are valuable measures to assess changes in voice and respiratory function, inclusion of s/z ratio (Eckel & Boone, 1981) in the primary outcome measures or initial screening procedures would help discriminate the cause of the functional presentations of short utterances, breathy voice, reduced volume, and poor intelligibility. Using this measure as a screening for inclusion criteria would help to ensure that the treatment is optimal for the patient. Use of s/z ratio as a primary outcome measure could provide information as to how the treatment protocol affects both respiratory function and voice.

Consideration for home programs either completed by the patient or augmented by the caregiver could also be of value. Training caregivers or patients complete this or a modified version of the protocol in the home environment may increase maintenance of the changes achieved during treatment. Furthermore, therapy time could be utilized to make progress in other areas such as language development if the rib cage ROM can be maintained by implementation of the protocol at home.

The ultimate goal of therapy is to maximize communicative effectiveness. Future studies might seek to determine if the motor speech improvements derived from the treatment presented in this study contribute to production of longer, more complex utterances. If increased SBU leads to increased mean length of utterance then there would be evidence to support what is a commonly held belief at this time that enhanced respiratory function enables a child to produce more language. This study did not measure any aspects of communication beyond speech intelligibility. However in order to determine whether the treatment had any effect on a child's communicative effectiveness beyond the treatment setting, a more detailed measure of functional communication could be used. Poor speech intelligibility limits communicative interactions, participation in life situations, and perceived quality of life (Pennington et al., 2013). A measure of this sort could examine the carryover of motor speech changes elicited in therapy and/or identify optimal communication environments and communication partners to maximize communicative effectiveness.

The results of this study provide evidence for a line of research that evaluates practices of other disciplines and their possible impact on speech outcomes. OTs and PTs, especially, have valuable information that SLPs should consider incorporating in to treatment protocols and research agendas.

Clinical Implications

Language impairments are often present in children with CP and should be targeted in speech-language therapy services. The sound pressure level results of MPD of /a/ likely measures the transient effects of stretch, not permanent changes in the muscle capability. Therapists may be able to use this temporary improvement prior to language therapy to enable more complex expressive language practice and skill learning in the treatment setting. Treatment including increased dosage and more active practice could result in more permanent motor and ROM changes allowing for continued language practice after treatment sessions. Only extension of the present study can confirm or refute this hypothesis.

A benefit of this protocol enables the stretches to be augmented by therapists in patients with decreased cognition or if cognition is uncertain due to poor communication abilities. Other treatment options require the ability to follow directions and an understanding of concepts that may exceed the patient's cognitive abilities. The behaviors used to measure progress can be modified based on the cognition and motor control of the patient.

In addition to addressing the limitations in current research, this study's procedures give information regarding the feasibility of implementing this treatment in typical treatment settings. All of the participants were seen at school outside of instructional time as to not interfere with any ongoing treatments. The short duration of the treatment allowed ease of scheduling into the participants' present schedules.

While this study has established the treatment efficacy for a manual therapy treatment, direct and systematic replication is needed before determining treatment effectiveness (phase 3) (Kratochwill et al., 2010). However, because SLPs have clients in need of manual therapy at this time, the raw data for all participants are included in Appendices J to N to assist clinicians in

deciding if they have patients who may benefit from this protocol. SLPs interested in implementing this protocol should collaborate with a PT to ensure proper technique. If patients require additional therapy goals, manual therapy treatment could be completed prior to articulation and language therapies that may be the focus of a given session.

I encourage SLPs to utilize s/z ratio to assist in identifying whether respiratory or phonatory impairments (or a combination of the two) are contributing to the motor speech disorder. Perceptually, respiratory impairments and phonatory impairments may sound similar during speech tasks; therefore, it is important to determine the status of each subsystem prior to initiation of this manual treatment protocol. Furthermore, some SLPs may be uncomfortable implementing this type of therapy due to lack of experience. I encourage those therapists to consult with the patient's PT. The PTs could be educated on the role of the in speech production and the benefits of increased ROM of the rib cage for the production of speech. PT could possibly support speech therapy efforts by providing manual therapy or other treatments to reduce spasticity of the resulting in increased level of functioning for the patient.

Contributions of each healthcare discipline add to the overall success of any treatment plan. It is vital that SLPs understand the impact that other disciplines' treatments may have on speech-language outcomes. Likewise, it is important for other disciplines to understand how their treatments affect speech-language outcomes. In addition to rib cage ROM, trunk support, and positioning are other areas that the PT could support the SLP in increasing respiratory function for increased speech outcomes for complex cases. Referral to or collaboration with PT could greatly impact our speech outcomes.

Limitations

Several limitations should be considered. The sound pressure level measures of MPD of /a/ likely measures the transient effects of stretch, not permanent changes in the muscle capability. Although this is discussed as a limitation, practitioners should use this to their advantage when devising treatment plans by implementing manual therapy prior to and in conjunction with motor practice to achieve therapy goals. Katalinic et al. (2011) discusses in a systematic review of the literature the effectiveness is likely dependent on dosage and how the stretch is applied. While dosage is explicitly defined in the majority of the literature, type and procedures of stretch are not. More specificity is needed across disciplines.

The measurements of SPL and MPD of /a/ was used in previous studies because they are a standard in the diagnosis in voice disorders. Some participants were able to produce short bursts of phonation with higher sound pressure levels. The same participant would likely not have been able to reach the higher sound pressure level if they had sustained phonation. It is unclear if the participants' understanding of the prompt "Say /a/ as loud and as long as you can." elicited phonation attempts that included longer durations. The "louder" part of the prompt appeared to be comprehended and followed; however, the "longer" part was less evident in changes in performance. This should not be of concern with older participants or participants with higher cognition; however, in the case of the younger participants this prompt should be examined.

It should be noted randomized lists of 5-word sentences from Intelligibility of Dysarthric Speech (Yorkston & Beukelman, 1981) were used to collect the speech samples from which SBU counts were extracted. Although, participants were rarely able to correctly imitate the complete sentence the amount of cognitive load may have contributed to or interfered with motor

speech performance. The syllables present in the prompts per phase ranged from 64 to 76 syllables. The individual sentences ranged from 5 to 9 syllables. These differences should be considered when interpreting the present results and in design of future studies.

CHAPTER 6. CONCLUSION

In conclusion, the results presented provide evidence to support a large treatment effect for a manual therapy protocol on speech outcomes including SPL, SBU, and chest expansion. The current evidence was less consistent for MPD and intelligibility measures. Only direct and systematic replication utilizing single subject design will enable results to be confirmed and generalized. This study is the first to discuss using manual therapy treatments that are proven to increase rib cage ROM to elicit speech outcomes. Using motor learning principles has proved successful in treating motor speech disorders; however, addressing individual structural constraints has not. This study is the first to apply that component to treating motor speech disorders in children.

If the results of this study are replicated, the course of treatment for children with neurological impairments may be altered. By addressing constraints prior to motor or language practice, treatment outcomes could be improved. Although this treatment does not require active participation, the motor practice required for motor learning and/or cortical change does. It is unclear at this time what role that may play in the implementation decisions related to this protocol.

According to the parameters defined by Kratochwill (2010), this study “meets evidence standards” (p.14) for design quality and presents “strong evidence” (p. 21) of treatment efficacy. The criteria indicate the present study adds a strong piece of evidence to the literature, addressing rib cage ROM to increase speech outcomes in children with spastic CP. Furthermore, these results hold promise for other disorders with a spastic component. Additionally, it introduces the application of treatment from other therapy disciplines to address speech therapy outcomes in individuals with motor speech disorders.

REFERENCES

- Abdel-Hamid, H. Z., & Zeldin, A. S. (2013). Cerebral palsy. <http://emedicine.medscape.com/article/1179555-overview> - aw2aab6b2b4aa
- Anderson, V., Spencer-Smith, M., & Wood, A. (2011). Do children really recover better? Neurobehavioral plasticity after early brain insult. *Brain*, 134, 2197-2221.
- Association, A. S.-L.-H. (2007). Scope of Practice in Speech-Language Pathology. Retrieved September 10, 2014, from <http://www.asha.org/policy>
- Association, A. S.-L.-H. (2010). Code of Ethics. from <http://www.asha.org/policy>
- Association, A. S.-L.-H. (2011). Speech-Language Pathology Medical Review Guidelines. Retrieved September 10, 2014, from <http://www.asha.org/practice/reimbursement/SLP-medical-review-guidelines/>
- Attanasio, J. S. (1994). Inferential statistics and treatment efficacy studies in communication disorders. *Journal of Speech, Language, and Hearing Research*, 37, 755-759.
- Bilan, N., & Poorshiri, B. (2013). The role of chest physiotherapy in prevention of postextubation atelectasis in pediatric patients with neuromuscular diseases. *Iran J Child Neurol*, 7, 21-24.
- Boersma, P., & Weenick, D. (2002). PRAAT. Retrieved September 10, 2014, 2014, from <http://www.pratt.org>
- Bovend'Eerdt, T. J., Newman, M., Barker, K., Dawes, H., Minelli, C., & Wade, D. T. (2008). The effects of stretching in spasticity: A systematic review. *Archives of Physical Medical Rehabilitation*, 89, 1395-1406.
- Busk, P. L., & Serlin, R. C. (1992). Meta-analysis for single-case research. In T. K. J. L. (Eds.) (Ed.), *Single-case research designs and analysis: New directions for psychology and education* (pp. 187-212). Hillsdale, NJ: Laurence Erlbaum Associates.
- Butler, C., & Darrah, J. (2001). Effects of neurodevelopmental treatment (NDT) for cerebral palsy: an AACPD evidence report. *Developmental Medicine & Child Neurology*, 43, 778-790. doi: doi:10.1017/S0012162201001414
- Byiers, B. J., Reichle, J., & Symons, F. J. (2012). Single-subject experimental design for evidence-based practice. *American Journal of Speech Language Pathology*, 21, 397-414. doi: 10.1044/1058-0360(2012/11-0036)
- Carr, J. H., Shepard, R. B., & Ada, L. (1995). Spasticity: Research findings and implications for intervention. *Physiotherapy*, 81, 421-429.

- Carr, L. J., Harrison, L. M., Evans, A. L., & Stephens, J. A. (1993). Patterns of central motor reorganization in hemiplegic cerebral palsy. *Brain* 116, 1223-1247.
- Cielo, C. A., & Cappellari, V. M. (2008). Maximum phonation time in pre-school children. *Brazilian Journal of Otorhinolaryngology*, 74, 552-560.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd. ed.). Hillsdale, NJ: Erlbaum.
- Dawson-Caswell, M., & Muncie, H. L. (2011). Respiratory syncytial virus infection in children. *American Family Physician*, 83, 141-146.
- Donovan, N. J., Kendall, D. L., Young, M. E., & Rosenbek, J. C. (2008). The communicative effectiveness survey: preliminary evidence of construct validity. *American Journal of Speech Language Pathology*, 17, 335-347. doi: 10.1044/1058-0360(2008/07-0010)
- Druz, W. S., & Sharp, J. T. (1981). Activity of respiratory muscles in upright and recumbent humans. *Journal of Applied Physiology: Respiratory, Environmental, Exercise Physiology*, 51, 1552-1561.
- Eckel, F. C., & Boone, D. R. (1981). The s/z ratio as an indicator of laryngeal pathology. *Journal of Speech and Hearing Disorders*, 46, 147-149.
- Epperson, S., Blanton, L., Kniss, K., Mustaquim, D., Steffens, C., Wallis, T., . . . Chaves, S. S. (2014). Influenza activity - United States 2013-2014 season and composition of the 2014-2015 influenza vaccines. *Morbidity and Mortality Weekly Report*, 63, 483-490.
- Fox, C., Ebersbach, G., Ramig, L., & Sapis, S. (2012). LSVT LOUD and LSVT BIG: Behavioral Treatment Programs for Speech and Body Movement in Parkinson Disease. *Parkinsons Dis*, 2012, 391946. doi: 10.1155/2012/391946
- Fox, C. M., & Boliek, C. A. (2012). Intensive voice treatment (LSVT LOUD) for children with spastic cerebral palsy and dysarthria. *Journal of Speech, Language, and Hearing Research*, 55, 930-945. doi: 10.1044/1092-4388(2011/10-0235)
- Hardy, J. (1961). Intraoral breath pressure in cerebral palsy. *Journal of Speech and Hearing Disorders*, 26, 309-319.
- Heyvaert, M., & Onghena, P. (2013). Analysis of single-case data: Randomisation tests for measures of effect size. *Neuropsychological Rehabilitation*. doi: 10.1080/09602011.2013.818564
- Hidecker, M. J. C., Paneth, N., Rosenbaum, P. L., Kent, R. D., Lillie, J., Eulenberg, J., . . . Taylor, K. (2011). Developing and validating the Communication Function Classification System (CFCFS) for individuals with cerebral palsy. *Developmental Medicine & Child Neurology*, 53, 704-710.

- Hinkle, D. E., Wiersma, W., & Jurs, S. G. (2002). *Applied Statistics for the Behavioral Sciences* (5th ed.). Boston, MA: Cengage Learning.
- Hixon, T. J. (1973). Kinematics of the chest wall during speech production: Volume displacements of the rib cage, abdomen, and lung. *Journal of Speech and Hearing Research, 16*, 78-115.
- Hixon, T. J., & Hoit, J. D. (2000). Physical Examination of the Rib Cage Wall by the Speech-Language Pathologist. *American Journal of Speech Language Pathology, 9*, 179-196.
- Hodges, P. W., & Gandevia, S. C. (2000). Changes in intra-abdominal pressure during postural and respiratory activation of the human diaphragm. *Journal of Applied Physiology, 89*, 967-976.
- Hoit, J. D., Banzett, R. B., Brown, R., & Loring, S. H. (1990). Speech breathing in individuals with cervical spinal cord injury. *Journal of Speech and Hearing Research, 33*, 798-807.
- Hoit, J. D., Hixon, T. J., Watson, P. J., & Morgan, W. J. (1990). Speech breathing in children and adolescents. *Journal of Speech and Hearing Research, 33*, 51-69.
- Hustad, K. C., & Cahill, M. A. (2003). Effects of presentation mode and repeated familiarization on intelligibility of dysarthric speech. *American Journal of Speech Language Pathology, 12*, 198-208. doi: 10.1044/1058-0360(2003/066)
- Hustad, K. C., Jones, T., & Dailey, S. (2003). Implementing speech supplementation strategies: effects on intelligibility and speech rate of individuals with chronic severe dysarthria. *Journal of Speech, Language, and Hearing Research, 46*, 462-474.
- Hustad, K. C., Schueler, B., Schultz, L., & DuHadway, C. (2012). Intelligibility of 4-year-old children with and without cerebral palsy. *Journal Speech, Language, and Hearing Research, 55*, 1177-1189. doi: 10.1044/1092-4388(2011/11-0083)
- Jerome, A., Passi, N., & Koli, S. (2013). A study to find the effect of myofascial release on chest expansion in cerebral palsy children. *International Journal of Current Research and Review, 5*, 8-14.
- Jones, H. N., Crisp, K. D., Moss, T., Strollo, K., Robey, R. R., Sank, J., . . . Kishnani, P. S. (2014). Effects of respiratory muscle training (RMT) in children with infantile-onset Pompe disease and respiratory muscle weakness. *Journal of Pediatric Rehabilitation Medicine, 7*, 255-265.
- Kahmi, A. G. (2011). Balancing certainty and uncertainty in clinical practice. *Language, Speech, and Hearing Services in Schools, 42*, 88-93. doi: 10.1044/0161-1461(2010/09-0078)

- Katalinic, O. M., Harvey, L. A., & Herbert, R. D. (2011). Effectiveness of stretch for the treatment and prevention of contractures in people with neurological conditions: A systematic review. *Physical Therapy, 91*, 11-24.
- Kent, R. D., Kent, J. F., & Rosenbek, J. C. (1987). Maximum performance test of speech production. *Journal of Speech and Hearing Disorders, 52*, 367-387.
- Knox, V., & Evans, A. L. (2002). Evaluation of the functional effects of a course of Bobath therapy in children with cerebral palsy: a preliminary study. *Developmental Medicine & Child Neurology, 44*, 447-460.
- Koman, L. A., Smith, B. P., & Schilt, J. S. (2004). Cerebral Palsy. *The Lancet*, 1619-1631.
- Kratochwill, T. R., Hitchcock, J., Horner, R. H., Levin, J. R., Odom, S. L., Rindskoph, D. M., & Shadish, W. R. (2010). Single-case design technical documentation. Version 1.0. Retrieved July 29, 2014, 2014, from http://ies.ed.gov/ncee/wwc/pdf/reference_resources/wwc_scd.pdf
- Krigger, K. W. (2006). Cerebral Palsy: An Overview. *American Family Physician, 73*, 91-100.
- Lee, D. R., Kim, Y. H., Kim, D. A., Lee, J. A., Hwang, P. W., & You, S. H. (2014). Innovative strength training-induced neuroplasticity and increased muscle size and strength in children with spastic cerebral palsy: An experimenter-blind case study-three-month follow-up. *NeuroRehabilitation, 35*, 131-136.
- Lee, J., Hustad, K. C., & Weismer, G. (2014). Predicting speech intelligibility with a multiple speech subsystems approach in children with cerebral palsy. *Journal of Speech, Language, and Hearing Research, 57*, 1666-1678.
- Levy, E. S. (2014). Implementing two treatment approaches to childhood dysarthria. *International Journal Speech-Language Pathology, 16*, 372-385
- Litman, R. S. (2013). *Basics of Pediatric Anesthesia*. New York, NY: Ronald S. Lithman.
- Littleton, S. R., Heriza, C. B., Mullens, P. A., Moerchen, V. A., & Bjornson, K. (2011). Effects of positioning on respiratory measures in individuals with cerebral palsy and severe scoliosis. *Pediatric Physical Therapy, 23*, 159-169. doi: 10.1097/PEP.0b013e318218e306
- Maas, E., & Farinella, K. A. (2012). Random versus blocked practice in treatment for childhood apraxia of speech. *Journal of Speech, Language, and Hearing Research, 55*, 561-578.
- Maas, E., Robin, D. A., Austermann Hula, S. N., Freedman, S. E., Wulf, G., Ballard, K. J., & Schmidt, R. A. (2008). Principles of Motor Learning in Treatment of Motor Speech Disorders. *American Journal of Speech Language Pathology, 17*, 277-298. doi: 10.1044/1058-0360(2008/025)

- Maner, K. J., Smith, A., & Grayson, L. (2000). Influences of utterance length and complexity on speech motor performance in children and adults. *Journal of Speech, Language, and Hearing Research*, 43, 560-573.
- Massery, M. (1991). Chest development as a component of normal motor development: implications for pediatric physical therapists. *Pediatric Physical Therapy*, 3, 3-8.
- Massery, M. (2006). *Multisystem consequences of impaired breathing mechanics and/or postural control* (4th ed.). St. Louis, MO: Elsevier Health Sciences.
- Massery, M. (2012). *If you can't breathe, you can't function*. Paper presented at the Woman's Hospital, Baton Rouge, LA.
- McReynolds, L., & Kearns, K. (1983). *Single-subject experimental designs in communicative disorders*. Baltimore, MD: University Park Press.
- Miller, F. (2007). *Physical Therapy of Cerebral Palsy*. New York, NY: Springer Science and Business Media, Inc.
- Mozzoni, D. (2015). Audacity (Version 3.0): Creative Commons Attribution License.
- Palisano, R., Begnoche, D. M., Chiarello, L. A., Bartlett, D. J., McCoy, S. W., Chang, H. J., . . . Chang, H. J. (2012). Amount and Focus of Physical Therapy and Occupational Therapy for Young Children with Cerebral Palsy. *Physical & Occupational Therapy in Pediatrics*, 32, 368-382.
- Parham, D. F. (2013). Speech-related breathing in infants: How much do we really know? *SIG 5 Perspectives on Speech Science and Orofacial Disorders*, 23, 27-33.
- Park, E. S., Park, J. H., Rha, D. W., Park, C. I., & Park, C. W. (2006). Comparison of the ratio of upper to lower chest wall in children with spastic quadriplegic cerebral palsy and normally developed children. *Yonsei Medical Journal*, 47, 237-242.
- Pennington, L., James, P., McNally, R., Pay, H., & McConchaie, H. (2009). Analysis of compositional data in communication disorders research. *Journal of Communication Disorders*, 42, 18-28.
- Pennington, L., Miller, N., Robson, S., & Steen, N. (2010). Intensive speech and language therapy for older children with cerebral palsy: a systems approach. *Developmental Medicine & Child Neurology*, 52, 337-344.
- Pennington, L., Roelant, E., Thompson, V., Robson, S., Steen, N., & Miller, N. (2013). Intensive dysarthria therapy for younger children with cerebral palsy. *Developmental Medicine & Child Neurology*, 55, 464-471.

- Pennington, L., Smallman, C., & Farrier, F. (2006). Intensive dysarthria therapy for older children with cerebral palsy: findings from six cases. *Child Language Teaching and Therapy*, 22, 255-273. doi: 10.1191/0265659006ct307xx
- Perdices, M., & Tate, R. L. (2009). Single-subject designs as a tool for evidence-based clinical practice: Are they unrecognised and undervalued? *Neuropsychological Rehabilitation*, 19, 904-927. doi: 10.1080/09602010903040691
- Pin, T., Dyke, P., & Chan, M. (2006). The effectiveness of passive stretching in children with cerebral palsy. *Developmental Medicine & Child Neurology*, 48, 855-862. doi: 10.1111/j.1469-8749.2006.tb01236.x
- Riley, D. A., & Van Dyke, J. M. (2012). The effects of active and passive stretching on muscle length. *Physical Medicine and Rehabilitation Clinics of North America*, 23, 51-57.
- Rvachew, S., Hodge, M., & Ohberg, A. (2005). Obtaining and interpreting maximum phonation performance tasks from children: A tutorial. *Journal of Speech-Language Pathology and Audiology*, 29, 146-157.
- Smith, A. (2006). Speech motor development: Integrating muscles, movements, and linguistic units. *Journal of Communication Disorders*, 39, 331-349. doi: 10.1016/j.jcomdis.2006.06.017
- Solomon, N. P., & Charron, S. (1998). Speech breathing in able-bodied children and children with cerebral palsy: A review of the literature and implications for clinical intervention. *American Journal of Speech Language Pathology*, 7, 61-78.
- Stathopoulos, E. T., & Sapienza, C. M. (1997). Developmental changes in laryngeal and respiratory function with variations in sound pressure level. *Journal of Speech, Language, and Hearing Research*, 40, 595-614.
- Sterling, C., Taub, E., Davis, D., Rickards, T., Gauthier, L. V., Griffin, A., & Uswatte, G. (2013). Structural neuroplastic change after constrain-induced movement therapy in children with cerebral palsy. *Pediatrics*, 131, 2012-2051.
- Tate, R. L., Perdices, M., Rosenkoetter, U., Wakim, D., Godbee, K., Togher, L., & McDonald, S. (2013). Revision of a method quality rating scale for single-case experimental designs and n-of-1 trials: the 15-item Risk of Bias in N-of-1 Trials (RoBiNT) Scale. *Neuropsychological Rehabilitation*, 23, 619-638. doi: 10.1080/09602011.2013.824383
- Theis, N., Korff, T., Kairon, H., & Mohagheghi, A. A. (2013). Does acute passive stretching increase muscle length in children with cerebral palsy? *Clinical Biomechanics*, 28, 1061-1067.

- Thomas-Stonell, N., Oddson, B., Robertson, B., Walker, J., & Rosenbaum, P. (2012). *Focus on the Outcomes of Communication Under Six*. Toronto, ON, Canada: Holland Bloorview Kids Rehabilitation Hospital.
- van Lieshout, P. H. (2003). PRAAT Short Tutorial. Retrieved December 10, 2014, 2015, from http://web.stanford.edu/dept/linguistics/corpora/material/PRAAT_workshop_manual_v421.pdf
- Varnado, C., Donovan, N. D., & Gonsoulin, C. (2014). Treatment effect of chest mobilization protocol on speech outcomes for a child with severe motor impairments: A single subject design. *Manuscript submitted for publication*.
- Wiig, E. H., Secord, W. A., & Semel, E. (2004). *Clinical Evaluation of Language Fundamentals Preschool* (2 ed.). San Antonio, TX: NCS Pearson, Inc.
- Wilcox, K., & Morris, S. (1999). *Children's Speech Intelligibility Measure*. San Antonio, TX: The Psychological Corporation.
- Workinger, M. S., & Kent, R. D. (1991). Perceptual analysis of the dysarthrias in children with athetoid and spastic cerebral palsy. In K. M. Y. C.A. Moore, & D.R. Beukelman (Ed.), *Dysarthria and apraxia of speech* (pp. 109-126). Baltimore, MD: Brookes.
- Yorkston, K. M., & Beukelman, D. R. (1981). Communication Efficiency of Dysarthric Speakers as Measured by Sentence Intelligibility and Speaking Rate. *Journal of Speech and Hearing Disorders*, 46, 296-301.
- You, S. H., Jang, S. H., Yun-Hee, K., Kwon, Y. H., Barrow, I., & Hallett, M. (2005). Cortical reorganization induced by virtual reality therapy in a child with hemiparetic cerebral palsy. *Developmental Medicine & Child Neurology*, 47, 628-635.

APPENDIX A. ITEMS IN ROBINT SCALE

Items in RoBiNT Scale

Internal validity subscale

- 1.Design
- 2.Randomisation
- 3.Sampling behaviour (all phases)
- 4.Blinding patient/therapist
- 5.Blinding assessors
- 6.Inter-rater reliability
- 7.Treatment adherence

External validity and interpretation subscale

- 8.Baseline characteristics
 - 9.Therapeutic setting
 - 10.Dependent variable (target behaviour)
 - 11.Independent variable (intervention)
 - 12.Raw data record
 - 13.Data analysis
 - 14.Replication
 - 15.Generalisation
-

(Tate et al., 2013)

APPENDIX B. IRB APPROVAL

ACTION ON PROTOCOL APPROVAL REQUEST

TO: Neila Donovan
COMD

FROM: Dennis Landin
Chair, Institutional Review Board

DATE: October 17, 2014

RE: IRB# 3375

TITLE: Treatment efficacy of manual therapy on speech outcomes in children with spastic cerebral palsy: A single-subject experimental design



Institutional Review Board
Dr. Dennis Landin, Chair
130 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.5983
irb@lsu.edu | lsu.edu/irb

New Protocol/Modification/Continuation: Modification

Brief Modification Description: 1) Change of title 2) Inclusion of a sham treatment in the withdrawal phase (ABAB) 3) Inclusion of "Permission to Photograph" and "Child Assent" Forms 4) Study length decreased from 10 weeks to 20 sessions lasting 4-6 weeks 5) Adding 10 participants 6) Adding secondary outcomes: syllables per breath unit, chest expansion, abdominal protrusion 7) Age range expanded to 4-10 years old

Review type: Full ☐ Expedited ☒ **Review date:** 10/16/2014

Risk Factor: Minimal ☐ Uncertain ☒ Greater Than Minimal ☐

Approved ☒ **Disapproved** ☐

Approval Date: 10/16/2014 **Approval Expiration Date:** 10/15/2015

Re-review frequency: (annual unless otherwise stated)

Number of subjects approved: 11

LSU Proposal Number (if applicable): _____

Protocol Matches Scope of Work in Grant proposal: (if applicable) _____

By: Dennis Landin, Chairman 

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING –

Continuing approval is **CONDITIONAL** on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.

**All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at <http://www.lsu.edu/irb>*

APPENDIX C. INFORMED CONSENT

Consent Form

Project Title: Treatment effect of a manual therapy protocol on speech outcomes for children with spastic cerebral palsy: A single subject experimental design

Performance Site:

Investigators: The following investigators are available for questions, Monday-Friday 8:00 a.m.-4:30 p.m.

Chantelle B. Varnado, M.S. CCC-SLP

Neila Donovan, Ph.D., CCC-SLP

Department of Communication Disorders, LSU

Department of Communication Disorders, LSU

(225) 405-8627

(225)578-3938

Purpose of the Study: To know if stretching rib muscles helps make speech louder.

Inclusion Criteria: good hearing and vision, able to follow simple directions, and has a motor delay

Exclusion Criteria: active seizure activity, uncontrolled asthma, upcoming surgeries, significant scoliosis affect breathing

Description of the Study: The study will last four weeks, 2 weeks of treatment and two weeks with no treatment. We will stretch your child's rib muscles for 15 minutes daily during the weeks of treatment. This will be added to your child's therapy plan. Your child will get all of his/her other therapies as usual. After stretching, we will measure how loud and how long your child can make the "ah" sound. We will also measure during the weeks your child does not receive treatment.

Benefits: You will not be paid for this study. You and your child are helping us learn more about stretching and speech.

Risks: Many children receive these stretches. They do not put your child's health at risk. We will watch your child carefully for any problems.

Right to Refuse: This is a volunteer study. You do not have to be in it. If you decide that you do not want your child in the study, you can say no or stop the study at any time. Even if you decide not to be in the study, it will not change your child's care.

Privacy: We will protect your child's privacy. We replace names with secret codes. Only my research helpers and I know the code. We will keep everything double-locked. We also use a special password to get in our computer. We never use any information that could identify your child if we write about this study.

Financial Information: There is no cost for participation in this study, and you will not be paid for participation in this study.

Thank you for your participation!

If you have any questions about the study, you can ask the investigators at any time.

Signatures:

The researcher discussed the study with me. She answered all of my questions. I understand that if I have any other questions, I can call the researchers, Chantelle Varnado or Dr. Neila Donovan. I understand that if I have any questions about my rights or any other concern about the research, I can contact Denis Landin, Institutional Review Board, at (225)578-8692. I agree to let my child to be in the study described above. I understand that the researcher must give a signed copy of this consent form.

Signature of Parent

Date

APPENDIX D. PHOTO CONSENT FORM

RELEASE FOR VIDEO AND PHOTOGRAPHY

I, _____ (participant), give permission for
to be videotaped and/or photographed by students and research staff from the
Department of Communication Sciences and Disorders (COMD)/COR Laboratory.

All digital images will be used for the educational purposes of:

1. Gathering data for the study
2. Training graduate and undergraduate students
3. Sharing the results of the study
4. Public relations media and social media (Facebook) for the LSU COR Laboratory
and/or the college of Louisiana State University.

Signature / Date

COR Representative Signature/Date

Revised 08-13-2014

APPENDIX E. GROSS MOTOR FUNCTION LEVEL

Gross Motor Function Classification System for Cerebral Palsy

Robert Palisano, Peter Rosenbaum, Stephen Walter, Dianne Russell, Ellen Wood, Barbara Galuppi

Introduction & User Instructions

The Gross Motor Function Classification System for cerebral palsy is based on self-initiated movement with particular emphasis on sitting (truncal control) and walking. When defining a 5 level Classification System, our primary criterion was that the distinctions in motor function between levels must be clinically meaningful. Distinctions between levels of motor function are based on functional limitations, the need for assistive technology, including mobility devices (such as walkers, crutches, and canes) and wheeled mobility, and to much lesser extent quality of movement. Level I includes children with neuromotor impairments whose functional limitations are less than what is typically associated with cerebral palsy, and children who have traditionally been diagnosed as having "minimal brain dysfunction" or "cerebral palsy of minimal severity". The distinctions between Levels I and II therefore are not as pronounced as the distinctions between the other Levels, particularly for infants less than 2 years of age.

The focus is on determining which level best represents the child's present abilities and limitations in motor function. Emphasis is on the child's usual performance in home, school, and community settings. It is therefore important to classify on ordinary performance (not best capacity), and not to include judgments about prognosis. Remember the purpose is to classify a child's present gross motor function, not to judge quality of movement or potential for improvement.

The descriptions of the 5 levels are broad and are not intended to describe all aspects of the function of individual children. For example, an infant with hemiplegia who is unable to crawl on hands and knees, but otherwise fits the description of Level I, would be classified in Level I. The scale is ordinal, with no intent that the distances between levels be considered equal or that children with cerebral palsy are equally distributed among the 5 levels. A summary of the distinctions between each pair of levels is provided to assist in determining the level that most closely resembles a child's current gross motor function.

The title for each level represents the highest level of mobility that a child is expected to achieve between 6-12 years of age. We recognize that classification of motor function is dependent on age, especially during infancy and early childhood. For each level, therefore, separate descriptions are provided for children in several age bands. The functional abilities and limitations for each age interval are intended to serve as guidelines, are not comprehensive, and are not norms. Children below age 2 should be considered at their corrected age if they were premature.

An effort has been made to emphasize children's function rather than their limitations. Thus as a general principle, the gross motor function of children who are able to perform the functions described in any particular level will probably be classified at or above that level; in contrast the gross motor functions of children who cannot perform the functions of a particular level will likely be classified below that level.

Reference: Dev Med Child Neurol 1997;39:214-223
© 1997 CanChild Centre for Childhood Disability Research (formerly NCRU)

Gross Motor Function Classification System for Cerebral Palsy (GMFCS)

Before 2nd Birthday

- Level I Infants move in and out of sitting and floor sit with both hands free to manipulate objects. Infants crawl on hands and knees, pull to stand and take steps holding on to furniture. Infants walk between 18 months and 2 years of age without the need for any assistive mobility device.
- Level II Infants maintain floor sitting but may need to use their hands for support to maintain balance. Infants creep on their stomach or crawl on hands and knees. Infants may pull to stand and take steps holding on to furniture.
- Level III Infants maintain floor sitting when the low back is supported. Infants roll and creep forward on their stomachs.
- Level IV Infants have head control but trunk support is required for floor sitting. Infants can roll to supine and may roll to prone.
- Level V Physical impairments limit voluntary control of movement. Infants are unable to maintain antigravity head and trunk postures in prone and sitting. Infants require adult assistance to roll.

Between 2nd and 4th Birthday

- Level I Children floor sit with both hands free to manipulate objects. Movements in and out of floor sitting and standing are performed without adult assistance. Children walk as the preferred method of mobility without the need for any assistive mobility device.
- Level II Children floor sit but may have difficulty with balance when both hands are free to manipulate objects. Movements in and out of sitting are performed without adult assistance. Children pull to stand on a stable surface. Children crawl on hands and knees with a reciprocal pattern, cruise holding onto furniture and walk using an assistive mobility device as preferred methods of mobility.
- Level III Children maintain floor sitting often by "W-sitting" (sitting between flexed and internally rotated hips and knees) and may require adult assistance to assume sitting. Children creep on their stomach or crawl on hands and knees (often without reciprocal leg movements) as their primary methods of self-mobility. Children may pull to stand on a stable surface and cruise short distances. Children may walk short distances indoors using an assistive mobility device and adult assistance for steering and turning.
- Level IV Children floor sit when placed, but are unable to maintain alignment and balance without use of their hands for support. Children frequently require adaptive equipment for sitting and standing. Self-mobility for short distances (within a room) is achieved through rolling, creeping on stomach, or crawling on hands and knees without reciprocal leg movement.
- Level V Physical impairments restrict voluntary control of movement and the ability to maintain antigravity head and trunk postures. All areas of motor function are limited. Functional limitations in sitting and standing are not fully compensated for through the use of adaptive equipment and assistive technology. At Level V, children have no means of independent mobility and are transported. Some children achieve self-mobility using a power wheelchair with extensive adaptations.

Between 4th and 6th Birthday

- Level I Children get into and out of, and sit in, a chair without the need for hand support. Children move from the floor and from chair sitting to standing without the need for objects for support. Children walk indoors and outdoors, and climb stairs. Emerging ability to run and jump.
- Level II Children sit in a chair with both hands free to manipulate objects. Children move from the floor to standing and from chair sitting to standing but often require a stable surface to push or pull up on with their arms. Children walk without the need for any assistive mobility device indoors and for short distances on level surfaces outdoors. Children climb stairs holding onto a railing but are unable to run or jump.
- Level III Children sit on a regular chair but may require pelvic or trunk support to maximize hand function. Children move in and out of chair sitting using a stable surface to push on or pull up with their arms. Children walk with an assistive mobility device on level surfaces and climb stairs with assistance from an adult. Children frequently are transported when travelling for long distances or outdoors on uneven terrain.
- Level IV Children sit on a chair but need adaptive seating for trunk control and to maximize hand function. Children move in and out of chair sitting with assistance from an adult or a stable surface to push or pull up on with their arms. Children may at best walk short distances with a walker and adult supervision but have difficulty turning and maintaining balance on uneven surfaces. Children are transported in the community. Children may achieve self-mobility using a power wheelchair.

Level V Physical impairments restrict voluntary control of movement and the ability to maintain antigravity head and trunk postures. All areas of motor function are limited. Functional limitations in sitting and standing are not fully compensated for through the use of adaptive equipment and assistive technology. At Level V, children have no means of independent mobility and are transported. Some children achieve self-mobility using a power wheelchair with extensive adaptations.

Between 6th and 12th Birthday

Level I Children walk indoors and outdoors, and climb stairs without limitations. Children perform gross motor skills including running and jumping but speed, balance, and coordination are reduced.

Level II Children walk indoors and outdoors, and climb stairs holding onto a railing but experience limitations walking on uneven surfaces and inclines, and walking in crowds or confined spaces. Children have at best only minimal ability to perform gross motor skills such as running and jumping.

Level III Children walk indoors or outdoors on a level surface with an assistive mobility device. Children may climb stairs holding onto a railing. Depending on upper limb function, children propel a wheelchair manually or are transported when travelling for long distances or outdoors on uneven terrain.

Level IV Children may maintain levels of function achieved before age 6 or rely more on wheeled mobility at home, school, and in the community. Children may achieve self-mobility using a power wheelchair.

Level V Physical impairments restrict voluntary control of movement and the ability to maintain antigravity head and trunk postures. All areas of motor function are limited. Functional limitations in sitting and standing are not fully compensated for through the use of adaptive equipment and assistive technology. At level V, children have no means of independent mobility and are transported. Some children achieve self-mobility using a power wheelchair with extensive adaptations.

Distinctions Between Levels I and II

Compared with children in Level I, children in Level II have limitations in the ease of performing movement transitions; walking outdoors and in the community; the need for assistive mobility devices when beginning to walk; quality of movement; and the ability to perform gross motor skills such as running and jumping.

Distinctions Between Levels II and III

Differences are seen in the degree of achievement of functional mobility. Children in Level III need assistive mobility devices and frequently orthoses to walk, while children in Level II do not require assistive mobility devices after age 4.

Distinctions Between Level III and IV

Differences in sitting ability and mobility exist, even allowing for extensive use of assistive technology. Children in Level III sit independently, have independent floor mobility, and walk with assistive mobility devices. Children in Level IV function in sitting (usually supported) but independent mobility is very limited. Children in Level IV are more likely to be transported or use power mobility.

Distinctions Between Levels IV and V

Children in Level V lack independence even in basic antigravity postural control. Self-mobility is achieved only if the child can learn how to operate an electrically powered wheelchair.

✦ This work has been supported in part by the Easter Seal Research Institute and the National Health Research and Development Program.

✦ Distribution of the Gross Motor Function Classification System for Cerebral Palsy has been made possible by a grant from the United Cerebral Palsy Research and Educational Foundation, USA.

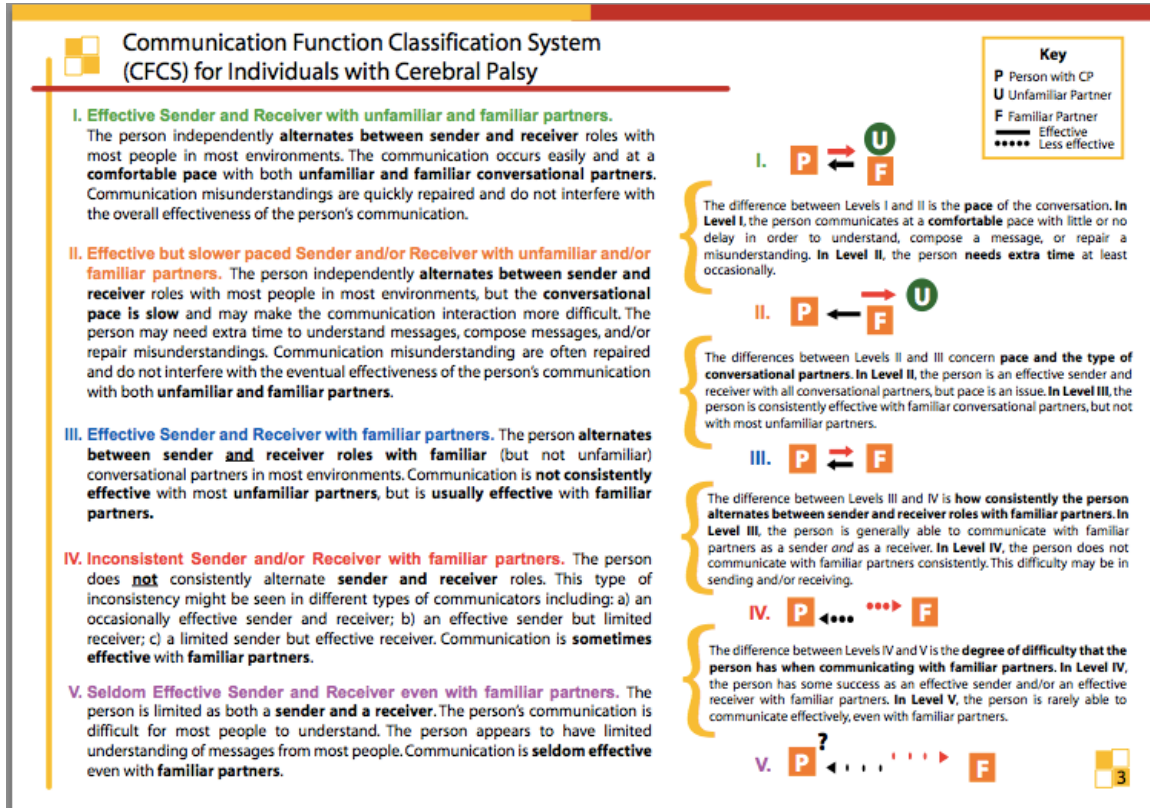
Want to know more? Contact:



Institute for Applied Health Sciences, McMaster University
1400 Main Street West, Rm. 408, Hamilton, ON, Canada L8S 4L7
Tel: 905-525-9140 Ext. 27850 • Fax: 905-522-6095
E-mail: canchild@mcmaster.ca
Website: www.ihhs.mcmaster.ca/canchild

(Palisano et al., 2012)

APPENDIX F. COMMUNICATION FUNCTION CLASSIFICATION SYSTEM



(Hidecker et al., 2011)

APPENDIX G. TREATMENT FIDELITY CHECKLIST

Participant #:	Date:	
Task	Comply	Failed to Comply
Tasks counter-balanced		
Anterior Intercostal Stretch		
Participant sit facing away from the therapist		
Therapist seated behind participant		
Use pads of fingers		
Begin at sternum moving laterally		
Repeated in each rib space		
Posterior Intercostal Stretch		
Participant sit facing the therapist		
Therapist seated in front of participant		
Use pads of fingers		
Begin at vertebrae moving laterally		
Repeated in each rib space		
Lateral Intercostal Stretch		
Participant sit facing away from the therapist		
Therapist "L"-shape hands		
Begin at highest rib space		
Work on lateral chest wall		
Participant's opposite arm over head		
Therapist cue "Reach"		
Therapy ball roll to opposite direction		
Completed bilaterally		
Bolster Stretch		
Participant side-lying on bolster		
Therapist "L"-shaped hands		
Begin at highest rib space		
Work on lateral chest wall		
Participant's opposite arm over head		
Therapist cue "Reach"		
Repeated in each rib space		
Intercostal Percussion		
Participant sit facing away from the therapist		
Therapist "L"-shaped hands		
Begin at highest rib space		
Prompt "Take a deep breath in, and push all the air out."		
Therapist shake and pull down on until exhalation is complete		
Repeated in each rib space		

APPENDIX H. MEASUREMENT FIDELITY CHECKLIST

Procedure	Participant	Session #	Yes	No
SLM 6 inches from mouth				
Microphone positioned in front of mouth				
Prompt "Say /a/ as loud and long as you can."				
Child seated upright and supported				
Reset button is pressed immediately after prompt				

Procedure	Participant	Session #	Yes	No
SLM 6 inches from mouth				
Microphone positioned in front of mouth				
Prompt "Say /a/ as loud and long as you can."				
Child seated upright and supported				
Reset button is pressed immediately after prompt				

Procedure	Participant	Session #	Yes	No
SLM 6 inches from mouth				
Microphone positioned in front of mouth				
Prompt "Say /a/ as loud and long as you can."				
Child seated upright and supported				
Reset button is pressed immediately after prompt				

Procedure	Participant	Session #	Yes	No
SLM 6 inches from mouth				
Microphone positioned in front of mouth				
Prompt "Say /a/ as loud and long as you can."				
Child seated upright and supported				
Reset button is pressed immediately after prompt				

Procedure	Participant	Session #	Yes	No
SLM 6 inches from mouth				
Microphone positioned in front of mouth				
Prompt "Say /a/ as loud and long as you can."				
Child seated upright and supported				
Reset button is pressed immediately after prompt				

Procedure	Participant	Session #	Yes	No
SLM 6 inches from mouth				
Microphone positioned in front of mouth				
Prompt "Say /a/ as loud and long as you can."				
Child seated upright and supported				
Reset button is pressed immediately after prompt				

APPENDIX I. RANDOMIZATION OF TREATMENT TASKS

Participant 1

Week 2: 4, 3, 5, 2, 1

Week 3: 2, 3, 4, 1, 5

Week 4: 1, 3, 2, 4, 5

Participant 2

Week 2: 1, 5, 2, 4, 3

Week 3: 4, 2, 3, 1, 5

Week 4: 3, 2, 1, 5, 4

Participant 3

Week 2: 3, 4, 2, 1, 5

Week 3: 3, 4, 5, 1 2

Week 4: 5, 2, 3, 4, 1

Participant 4

Week 2: 3, 5, 2, 4, 1

Week 3: 3, 2, 1, 4, 5

Week 4: 1, 2, 4, 5, 3

Participant 5

Week 2: 4, 2, 3, 5, 1

Week 3: 1, 3, 4, 5, 2

Week 4: 2, 4, 5, 1, 3

APPENDIX J. PARTICIPANT #1 RAW DATA

DATA COLLECTION

Participant #: 1 Age: 4 Diagnosis: Spastic Cerebral Palsy
 Gender: M GMFS: V CFCS III
 Receptive: 75 Expressive: 63 Core: 75

Week 1(A₁)

Sequence															
SPL	73.1	82.9	85.1	81.5	84.9	81.8	83.1	74.1	72.3	75.3	74.4	76.4	83.4	82.1	75.3
AVG SPL	80.57			82.73			76.50			75.37			80.27		
AVG Dur.	.34			.39			.34			.17			.28		
AVG Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
4.67 %	1.0			.50 in.			.25 in.			.75 in.			21.0 in.		
				.25 in.			.63 in.			.50 in.					
				.50 in.			.31 in.			.50 in.					

Week 2(B₁)

Sequence	4			3			5			2			1		
SPL	81.3	83.3	82.6	87.3	88.6	86.2	94.2	85.8	93.3	90.1	87	84.3	94	84.6	85.2
AVG SPL	82.3			87.31			91.1			87.13			87.93		
AVG Dur.	.31			.2			.27			.2			.22		
AVG Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
12.67 %	2.9			.69 in.			1.00 in.			1.25 in.			17.5 in.		
				.63 in.			1.06 in.			.75 in.					
				.81 in.			.88 in.			.81 in.					

Week 3 (A₂)

Sequence	2			3			4			1			5		
SPL	77.7	80.5	81.5	82	84.4	82.3	74.4	83.4	74.6	71.1	83.3	81.4	75.2	83.8	76
AVG SPL	79.9			82.9			77.47			78.8			78.33		
AVG Dur.	.25			.3			.32			.22			.25		
AVG Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
12.67 %	1.8			.50 in.			.75 in.			.31 in.			21.5 in.		
				.44 in.			.75 in.			.56 in.					
				.63 in.			.69 in.			.38 in.					

Week 4 (B₂)

Sequence	1			3			2			4			5		
SPL	85.6	84.4	78.4	87.6	91.3	88.2	87.4	90.6	93.2	90.3	89.5	89.2	88.3	93.4	94.9
AVG SPL	82.8			89.03			90.41			89.67			92.2		
AVG Dur.	.28			1.98			2.61			1.83			2.69		
AVG Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
16.67 %	2.3			.63 in.			.69 in.			.75 in.			20.0 in.		
				1.00 in.			1.13 in.			.88 in.					
				.88 in.			.56 in.			.56 in.					

APPENDIX K. PARTICIPANT #2 RAW DATA

DATA COLLECTION

Participant #: 2 Age: 4 Diagnosis: Spastic CP/Apraxia

Gender: F GMFS: IV CFCS: V

Receptive: 55 Expressive: 53 Core: 55

Week 1(A₁)

Sequence															
SPL	87.9	81.3	83.4	79.2	83.4	81.7	81.3	79.2	80.5	85.6	81.2	80.8	89.8	71.2	73.2
Avg SPL	84.2			81.43			80.33			82.57			78.01		
Avg Dur.	1.45			1.82			1.24			2.25			.8		
Avg Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
1.30%	3.4			.25 in.			.63 in.			.25 in.			19.0 in.		
				.25 in.			.50 in.			.25 in.					
				.13 in.			.44 in.			.19 in.					

Week 2(B₁)

Sequence	1			5			2			4			3		
SPL	90.7	85.1	87.7	91.8	82.1	97	97.3	90.4	93.2	88.8	96.3	91.2	86.5	92.5	92.3
Avg SPL	87.83			90.3			93.63			92.1			90.43		
Avg Dur.	1.15			1.22			1.67			1			.97		
Avg Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
0.00%	4.2			.69 in.			.56 in.			1.25 in.			19.5 in.		
				.88 in.			.75 in.			.75 in.					
				1.25 in.			.75 in.			1.75 in.					

Week 3 (A₂)

Sequence	4			2			3			1			5		
SPL	83.3	84.7	87.2	68.6	79.3	78.2	87.6	82.4	91.2	78.7	76.7	75.7	70.3	76.7	71.3
Avg SPL	85.07			75.37			87.07			77.03			72.77		
Avg Dur.	.72			1.06			.93			.95			1.24		
Avg Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
0.00%	3.2			.75 in.			.44 in.			.44 in.			19.0 in.		
				.50 in.			.38 in.			.63 in.					
				.50 in.			.31 in.			.50 in.					

Week 4 (B₂)

Sequence	3			2			1			5			4		
SPL	88.6	89.7	86.3	83.8	88.7	80.6	78.5	85.1	80.1	92.3	93.7	95.9	101.3	102.1	99.2
Avg SPL	88.2			84.37			81.23			93.97			100.87		
Avg Dur.	1.57			1.44			1.44			.97			1.39		
Avg Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
0.00%	5			1.00 in.			.75 in.			1.25 in.			19.0 in.		
				1.25 in.			1.13 in.			1.25 in.					
				.88 in.			1.19 in.			1.06 in.					

APPENDIX L. PARTICIPANT #3 RAW DATA

DATA COLLECTION

Participant #: 3 Age: 4 Diagnosis: Spastic CP

Gender: F GMFS: II CFCS: III

Receptive: 75 Expressive: 81 Core: 81

Week 1(A₁)

Sequence															
SPL	80.3	86.2	83.1	87.7	81.2	86.9	85.3	82.5	86.1	85.3	86.2	83.1	84.7	86.3	88.2
Avg SPL	83.2			85.27			84.63			84.87			86.4		
Avg Dur.	1.51			1.23			1.26			.81			.92		
Avg Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
14.00%	3.8			.38 in.			.25 in.			.50 in.			20.0 in.		
				.38 in.			.19 in.			.63 in.					
				.25 in.			.50 in.			.50 in.					

Week 2(B₁)

Sequence	3			4			2			1			5		
SPL	90.3	88.2	89.5	93.1	89.7	92.1	91.1	91.7	94.3	91.4	89.8	88.9	94.2	90.7	90.9
Avg SPL	89.33			91.63			92.37			90.03			91.93		
Avg Dur.	.81			1.54			.93			1.24			1.03		
Avg Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
15.67%	4.2			.81 in.			.56 in.			.94 in.			19.0 in.		
				.88 in.			.75 in.			1.00 in.					
				1.00 in.			.94 in.			1.13 in.					

Week 3 (A₂)

Sequence	3			4			5			1			2		
SPL	73.7	87.2	81.3	88.6	82.5	83.9	85.2	85.7	86.6	82.4	83.7	85.9	87.3	81.9	85.7
Avg SPL	80.73			85			85.83			84			84.97		
Avg Dur.	.79			.64			.67			.88			.73		
Avg Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
8.33%	3.5			.25i n.			.31 in.			.56 in.			20. 0 in.		
				.38 in.			.44 in.			.50 in.					
				.38 in.			.50 in.			.63 in.					

Week 4 (B₂)

Sequence	5			2			3			4			1		
SPL	95.7	91.7	93.9	102.1	97.9	101.3	93.5	100	98.2	101.3	99.9	97.6	100.4	96.6	98.8
Avg SPL	93.77			100.4			97.23			99.6			98.6		
Avg Dur.	.65			.92			.99			.59			1.01		
Avg Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
7.00 %	4.1			.56 in.			1.06 in.			.50 in.			20.0 in.		
				1.00 in.			.81 in.			.56 in.					
				.88 in.			.94 in.			.81 in.					

APPENDIX M. PARTICIPANT #4 RAW DATA

DATA COLLECTION

Participant #: 4 Age: 5 Diagnosis: Spastic CP

Gender: F GMFS: V CFCS: II

Receptive: 55 Expressive: 59 Core: 53

Week 1(A₁)

Sequence															
SPL	75.1	74.6	73.2	76.1	74.2	71.9	70.1	77.2	83.7	83.2	86.1	81.8	83.2	84.7	81.9
Avg SPL	74.3			74.07			73.43			83.7			83.27		
Avg Dur.	.9			1.22			2.01			2.27			1.60		
Avg Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
11.33%	6			.47 in.			.13 in.			.31 in.			21.0 in.		
				.25 in.			.13 in.			.25 in.					
				.19 in.			.25 in.			.38 in.					

Week 2(B₁)

Sequence	3			5			2			4			1		
SPL	89.2	87.3	89.7	84.2	87.3	89.7	89.9	89.3	89.4	87.2	88.8	83.9	86.9	83.7	82.7
Avg SPL	87.6			87.01			89.53			86.63			85.93		
Avg Dur.	1.28			2.09			2.59			.8			1.30		
Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
31.00 %	6.3			1.06 in.			.81 in.			.44 in.			20.0 in.		
				.88 in.			.50 in.			.63 in.					
				.63 in.			.69 in.			1.19 in					

Week 3 (A₂)

Sequence	3			2			1			4			5		
SPL	77.7	77.8	78.8	71.3	73.5	78	81.7	83.8	84	75.3	81.9	80.3	78.9	79.3	81.7
Avg SPL	78.1			76.27			83.12			79.17			79.9		
Avg Dur.	1.21			2.01			2.4						1.53		
Avg Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
17.67%	6.1			.1875			.125			.375			21.5		
				.25			.25			.3125					
				.25			.3125			.25					

Week 4 (B₂)

Sequence	1			2			4			5			3		
SPL	84.9	86.2	89.1	85.5	85.6	87.9	93.7	91.7	88.3	90.3	94.8	97.3	85.1	90.8	93.2
Avg SPL	86.73			86.33			91.23			94.13			89.7		
Avg Dur.	1.29			.94			1.13			.86			1.51		
Avg Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
16.67	5.7			1.00 in.			1.50 in.			.94 in.			19.0 in.		
				.81 in.			.63 in.			1.07 in.					
				.56 in.			1.88 in.			.94 in.					

APPENDIX N. PARTICIPANT #5 RAW DATA

DATA COLLECTION

Participant #: 5 Age: 6 Diagnosis: Spastic CP

Gender: F GMFS: II CFCS: II

Receptive: 77 Expressive: 83 Core: 88

Week 1(A₁)

Sequence															
SPL	80.3	75.3	82.1	96.5	94.8	92.8	87.3	83.2	90.1	95.9	95.5	94.7	93.7	88.1	87.3
Avg SPL	79.23			94.7			86.7			95.37			89.7		
Avg Dur.	1.24			1.47			4.89			5.05			3.06		
Avg Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
26.67%	5			.81 in.			1.00 in.			.38 in.			19.0 in.		
				.69 in.			.94 in.			.50 in.					
				.94 in.			.57 in.			.38 in.					

Week 2(B₁)

Sequence	4			2			3			5			1		
SPL	96	95.3	97.2	98.2	97.1	100.1	100.	100.	101.	97.7	94.7	96.3	96.9	99.1	97.7
Avg SPL	79.23			94.7			86.7			95.37			89.7		
Avg Dur.	10.20			13.1			1.64			2.13			1.53		
Avg Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
45.00%	6			.81 in.			.75 in.			.56 in.			19.0 in.		
				1.0 0 in.			.88 in.			.44 in.					
				.69 in.			.63 in.			.56 in.					

Week 3 (A₂)

Sequence	1			3			4			5			2		
SPL	91.3	93.2	96.1	96.7	96.0	99.0	84.3	101.6	96.2	98.1	93.4	91.3	94.1	93.2	91.7
Avg SPL	93.53			97.23			94.03			94.27			93		
Avg Dur.	2.21			2.95			2.69			3.58			6.53		
Avg Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
34.67%	2.5			.63 in.			.38 in.			.56 in.			19.6 in.		
				.56 in.			.75 in.			.31 in.					
				.63 in.			.56 in.			.44 in.					

Week 4 (B₂)

Sequence	2			4			5			1			5		
SPL	109.1	104.7	104.3	110.1	107.3	97.7	98.8	100.8	98.8	99.7	101.1	98.9	97.9	100.9	101.7
Avg SPL	106.03			104.9			99.47			99.9			100.17		
Avg Dur.	10.32			10.33			10.21			8.42			6.5		
Avg Intell.	SBU			Nipple			Axilla			Xyphoid			Abdomen		
11.33%	6.5			.88 in.			.6875			2.00 in.			19.0 in.		
				.75			.94 in.			1.38 in.					
				.9375			1.19 in.			1.56 in.					

APPENDIX O. SPRINGER COPYWRITE PERMISSION LETTER



March 13, 2015 Springer reference

2005Cerebral Palsy©Springer Science+Business Media, Inc. Freeman Miller
MD DOI 10.1007/b138647 Print ISBN 978-0-387-20437-6 Online ISBN 978-0-
387-27124-8

Material to be used: Figure 4.5 (p.106) Your project

PERMISSION LETTER

01_02

Requestor:

University: Purpose:

Chantelle B. Varnado chantelle.varnado@gmail.com Louisiana State
University Dissertation/Thesis

With reference to your request to reuse material in which Springer
Science+Business Media controls the copyright, our permission is granted
free of charge under the following conditions:

Springer material

- € represents original material which does not carry references to other sources (if material in question refers with a credit to another source, authorization from that source is required as well);
- € requires full credit (Springer and the original publisher, book/journal title, chapter/article title, volume, year of publication,

page, name(s) of author(s), original copyright notice) to the publication in which the material was originally published by adding: "With kind permission of Springer Science+Business Media";

- € figures, illustrations, and tables may be altered minimally to serve your work. Any other abbreviations, additions, deletions and/or any other alterations shall be made only with prior written authorization of the author and/or Springer Science+Business Media;
- € Springer does not supply original artwork or content. This permission
- € is non-exclusive;
- € is valid for one-time use only for the purpose of defending your thesis limited to university-use only and with a maximum of 100 extra copies in paper. If the thesis is going to be published, permission needs to be reobtained.
- € includes use in an electronic form, provided it is an author-created version of the thesis on his/her own website and his/her university's repository, including UMI (according to the definition on the Sherpa website: <http://www.sherpa.ac.uk/romeo/>);
- € is subject to courtesy information to the author (address is given in the publication);
- € is personal to you and may not be sublicensed, assigned, or transferred by you to any other person without Springer's written permission;
- € is only valid if no personal rights, trademarks, or competitive products are infringed. This license is valid only when the conditions noted above are met. Permission free of charge does not prejudice any rights we might have to charge for reproduction of our copyrighted material in the future.




Rights and Permissions Springer Science+Business Media Tiergartenstr.
17 69121 Heidelberg Germany

PERMISSION LETTER

01_02

APPENDIX P. LITMAN COPYWRITE PERMISSION

Litman, Ronald S 

To: Chantelle B. Varnado, ABD, CCC-SLP

RE: [Basics of Pediatric Anesthesia] Contact Us

March 13, 2015 11:28 AM

[Hide Details](#)

1

Hi Chantelle,

Permission is granted to use the figure but please give proper attribution as follows: "Illustration by Rob Fedirko. Reproduced with permission from: Litman, R. and Giles, M. Developmental Physiology and Pharmacology, in Basics of Pediatric Anesthesia, Ronald S. Litman (editor), Philadelphia, 2015"

I attached the higher quality jpg for you also.

Good luck with the dissertation.

Ron Litman

-----Original Message-----

From: Chantelle B. Varnado, ABD, CCC-SLP [<mailto:donotreply@wordpress.com>]

Sent: Thursday, March 12, 2015 10:13 AM

To: Litman, Ronald S

Subject: [Basics of Pediatric Anesthesia] Contact Us

VITA

Chantelle Varnado received her Bachelor of Arts degree in speech-language and hearing from Southeastern Louisiana University in Hammond, Louisiana in December 1999. She received her Master of Science in communication sciences and disorders from Southeastern Louisiana University in Hammond, Louisiana in August of 2001. She holds her Certificate of Clinical Competence from the American Speech-Language and Hearing Association. She plans to pursue a career in academia and extend her research addressing multimodal treatment interventions for medically complex children.